Evaluation of Chickpea Genotypes for Yield and Selected Agronomic Traits in Kenya

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DECLARATION

This thesis is my original work and has not been presented for degree in any other university.

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DEDICATION

This work is dedicated to my beloved late father Semere Mallu, brother Teclom Semere and all other family members (mother, brothers and sisters) with love. Without your support, prayers and encouragement, the whole journey would have been long and tough.

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ABBREVIATIONS

FAOSTAT	Food and Agricultural Organization Statistics
IBPGR	International Board of Plant Genetic Resources
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for Semi-arid Tropics
MOA	Ministry of Agriculture

ABSTRACT

Chickpea (*Cicer arietinum* L.) is an important source of vegetable protein in the world. It is a relatively new crop in Kenya and limited information is available on genetic variation for agronomic and yield traits. The determination of genetic variations, association among traits and seed yield is a pre-requisite for a breeding programme aimed at improvement of chickpea. The objectives of this study were to assess the genotypic variation for agronomic and yield traits and analyse the association among agronomic traits and determine seed yield. Fifty eight *desi* and 37 *kabuli* genotypes including two check varieties for each type were used for this study. Replicated field experiments were conducted in the long and short rain seasons of 2013 at Kabete and Juja using alpha lattice design. Data on agro-morphological traits were recorded using descriptors for chickpea. Data were analysed using SAS, 2013 (second edition) and Gen-Stat, 2014 (release 15.1). Genotypes and genotype by environment interactions were highly significantly different ($p < 0.001$) for all studied traits. Mean values for the studied traits varied among genotypes and across environments. Genotypes had different ranking for most agronomic traits across environments which indicated a crossover type of genotype by environment interactions. Flowering, maturity time, number of branches plant $^{-1}$, plant canopy width, number of pods plant $^{-1}$, total biomass yield ha $^{-1}$, seed yield ha $^{-1}$ and 100 seed weight were the main discriminating traits for both *desi* and *kabuli* types. Genotype ICC 9636 exceeded the check varieties for seed yield ha $^{-1}$ among *desi* type genotypes. The *desi* type also varied for six out of eight qualitative traits. Seed yield ha $^{-1}$ was positively and significantly correlated ($p < 0.05$) with biomass yield ha $^{-1}$, pod filling period, number of pods plant $^{-1}$, number of primary and secondary branches plant $^{-1}$ but negatively correlated with days to 50 % flowering and podding. For *kabuli* type of chickpea, the highest yielding genotypes were ICCV 05315, ICC 13461 and ICCV 07313. Seven and thirty seven genotypes exceeded the check varieties ICCV 00305 and ICCV 92318 respectively. Genotypes further varied for six qualitative traits for *kabuli* type of chickpea. Seed yield ha $^{-1}$ showed positive and highly significant correlation ($p < 0.001$) with total biomass yield ha $^{-1}$, number of pods plant $^{-1}$, plant canopy width and number of secondary branches plant $^{-1}$ but not significantly correlated with the other traits. The characters that were positively and significantly correlated with seed yield could be used for indirect selection of high yielding chickpea genotypes. The presence of substantial variations, the positively and significantly correlated traits with seed yield and a crossover type of genotype by environment interactions can be exploited in breeding programmes for improvement of chickpea in the region.

CHAPTER ONE

1.0. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop in the world, after dry bean and field pea (FAOSTAT, 2013). The crop accounts for 12 % of the world pulses production (Khan, Farhatullah & Khan, 2011). It is grown in arid and semi-arid regions of the world with a total global production of 11.6 million tons from 13.2 million hectares in 2011 (FAOSTAT, 2012). Two main types of chickpea cultivars are grown globally: the *desi* and *kabuli* types. The total yield production is quite low in most chickpea growing countries and a wide gap exists between the potential (5 ton ha $^{-1}$) and actual (0.96 ton ha $^{-1}$) yields (FAOSTAT, 2013). The low yields have been attributed to low genetic diversity of cultivated chickpea for yield and yield components (Malik *et al*., 2014) and various biotic (Aschochyta blight, Fusarium wilt, Pod borer dry root rot etc.) and abiotic (drought, extreme temperatures, salinity) stresses (Millan *et al.*, 2006, Upadhyaya *et al.*, 2008).

Chickpea is a multipurpose crop grown for dry seeds as pulse, green pods as vegetable source of food for human and also feed for livestock due to its high protein, vitamins, minerals and fibre contents. Chickpea seeds contain potassium calcium, sodium, magnesium, iron, copper and zinc which make it nutritionally the best edible pulse (Ferial & Esmat, 2011). The crop enhances intensive utilization of land in areas where land is limited and it can be grown as a second crop using residual moisture.

Chickpea requires no nitrogen fertilizers due to its ability to fix atmospheric nitrogen. It returns a large amount of residual nitrogen to the soil and adds organic matter. Fathma *et al*. (2008) reported that the crop fixes 68 – 138 kg nitrogen ha $^{-1}$ per growing season.

In Kenya, chickpea is a relatively new crop and preliminary studies show that chickpea is adapted to varied agro-ecological-zones of the country (Kibe & Onyari, 2006; ICRISAT, 2008) and its cultivation is gradually expanding in the Rift Valley and dry highlands. The crop is being promoted as a relay crop during short rainy season.

Chickpea is the most important staple pulse crop in Eritrea and leads in production and area under cultivation. The crop is mainly cultivated in central highlands and some lowlands areas. The crop contributes 58% of the total pulse production in the country. It provides substantial economic merits for many smallholder farm households as a source of protein for human and livestock. The *desi* type of chickpea is the most commonly grown. Chickpea grains are consumed in different forms such as *kollo* (roasted seed), *thithko* (boiled seeds), *kicha* (sole unleavened thin bread or mixed with cereals flour) and *shiro* (sauce made out of chickpea ground flour and *bukulti* (sprouts). Seeds are also consumed during the green pod stage as a vegetable (MOA, 2011).

Evaluation of crop germplasm is a pre-requisite, for which the future breeding work is based. The value of germplasm collection relies not only on the number of accessions it possesses, but also upon the genetic diversity present in those accessions for essential economic traits (Reddy *et al*, 2012). The development of high yielding varieties with broad genetic base and wider adaptation could help to increase the productivity of chickpea. Thus, if adopted, high yielding genotypes with broad genetic base have the capacity to immensely increase chickpea productivity and selected traits can be used as source of genes for hybridization.

The success of any breeding programme depends upon the extent of genetic variability in the base population. In addition to genetic variation, correlation of yield and yield components will serve to make an effective selection. In chickpea, Malik *et al*. (2009) reported significant genetic variation and positive correlation for yield and yield components characters.

1.1. Statement of the Problem

Chickpea is a relatively new pulse crop in Kenya with a potential seed yield production of 1.4 - 2.5 ton ha $^{-1}$ (Onyari *et al*., 2010), 0.219 - 2.87 ton ha $^{-1}$ (Mulwa *et al*., 2010). In most chickpea growing areas the main constraints reported to affect chickpea production include lack of high yielding varieties, abiotic stresses (drought and extreme temperatures) and biotic stresses (Ascochyta blight, Fusarium wilt and Pod borer) (Upadhyaya *et al*., 2011). These constraints could be attributed to low genetic variation for yield, agronomic and other economic traits. Limited information is available on genotypic variation of economic traits in chickpea germplasm present in the reference set of world core collection maintained at ICRISAT-Nairobi that have been identified for characterization and dissemination in

Eastern and Southern Africa. Assessment of such germplasm can provide practical information for selection of elite chickpea lines and thus, assist in devising future breeding strategies.

Eritrea has a large collection of chickpea germplasm. Despite its economic importance, the germplasm collection has not been adequately characterized and evaluated for agronomic, yield and other useful traits due to lack of qualified expertise and inadequate resources. In Kenya, chickpea cultivation is new and information pertaining to characterization and evaluation of chickpea is limited. This study was being conducted as part of collaboration programme between Kenya and Eritrea. The expertise learned from the study is expected to be applicable in Eritrea. It is of paramount importance to evaluate chickpea genotypes in order to identify those of superior performance or other useful traits for direct or future utilization of chickpea improvement.

1.2. Justification

Crop genetic resources are the basic raw materials for plant breeding. The presence of genetic variability is a pre-requisite for any breeding programme aimed at improving yield, enhancing resistance to biotic and abiotic stresses or improving quality. Germplasm sources with wide genetic basis for agronomic, yield components and tolerance to biotic and abiotic stresses could be utilized for developing high yielding varieties of chickpea. High yield could be achieved if the superior chickpea varieties possess broad genetic base with enhanced productivity and quality and thus contribute to food security. Though considerable research efforts and progress have been made at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), only a small proportion of accessions have been used in chickpea improvement due to lack of information on the essential traits. Upadhyaya *et al*. (2006) reported that during the period 1978-2004, only 91 germplasm accessions were used in the development of 3,548 advanced breeding lines. In chickpea, Anbessa and Bejiga (2002) and Keneni *et al.* (2012) reported highly significant variations of agronomic and yield traits and identified number of superior genotypes and suggested the potential of germplasm in obtaining superior varieties.

Chickpea research in Kenya is in its infancy stage and limited information is available on the performance of agronomic and yield traits. Likewise in Eritrea, little information is available on chickpea germplasm characterization. Assessing genetic variation of the available chickpea germplasm collection could help to devise suitable breeding strategy in chickpea. Results on morphological and recently molecular evaluation of chickpea germplasm obtained from other regions of the world cannot be applied directly to Kenya and Eritrea due to differences in environmental conditions.

1.3. General Objective

To contribute to diversified pulse production in Kenya and Eritrea through evaluation of chickpea genotypes for yield and agronomic performance.

1.3.1. Specific Objectives

1. To assess the variation among chickpea genotypes for yield and selected agronomic traits
2. To determine the relationships among selected quantitative traits and with yield in chickpea

1.4. Null Hypothesis

I. There is no difference among chickpea genotypes with respect to yield and selected agronomic traits.

II. There is no relationship among quantitative traits with seed yield.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Origin and Distribution

Chickpea is one of the first pulse crops domesticated and most probably originated in an area of South-eastern Turkey adjoining Syria (Toker, 2009). The crop is now cultivated throughout arid and semi-arid regions of the world that characterized by moisture stress and low soil fertility (Gaur *et al.,* 2008). Major chickpea growing areas are almost completely in the arid and semi-arid zones of the world. Globally it is grown in more than 52 countries and in an area of 13.2 million hectares with 11.6 million tons of production (FAOSTAT, 2012). About 97 % of chickpea cultivation is in developing countries, where the crop is largely grown under marginal areas with moisture stress conditions. India is the largest chickpea producer in the world. Other chickpea producing regions are Eastern Africa, North Africa, Mediterranean and Near-East regions, Australia, Southern Europe and North and South America (Upadhyaya *et al.,* 2007).

2.2. Botanical Description

Cultivated chickpea, is a self-pollinated, diploid (2n =16) annual pulse crop with a relatively small genome of 740 Mb (Arumuganathan & Earle, 1991). Chickpea belongs to genus *Cicer,* family Fabaceae. The crop is herbaceous, a small bush with diffused spreading branches from the base, which reach a height of 20 – 150 cm depending on cultivar and growing conditions. Its stem is mostly erect, branched and solid and has strong deep taproot system which makes it relatively drought tolerant. The crop has an indeterminate growth habit which continues to produce vegetative growth whenever soil moisture, temperature and other environmental factors are favorable (Williams & Saxena, 1991). Chickpea has pinnate type of compound leaves in which the leaf lamina is differentiated into a rachis and a number of leaflets. These leaflets are generally odd in number and borne directly on the rachis.

2.3. Types of Cultivated Chickpea

There are two types of cultivated chickpea produced globally namely *desi* and *kabuli*.

***Desi* type**: it is characterized by small seed size of various colours, thick seed coat due to rigid and extensively thickened palisade layer with pectic and protein, high percentage of fibre and angular seed shape with rough testa texture. *Desi* types have semi erect to semi-spreading growth, presence of anthocyanin on the stem pink, purple or white flower colour and small leaves. Seeds are mostly decorticated and processed in to flour but some consumed as whole (Wood *et al*., 2012). *Desi* type covers about 85 % of the global chickpea areas and it predominantly grown in South and East Asia, Ethiopia, Australia and Eritrea.

Kabuli* type*: is characterized by big size of seeds with whitish-cream colour, thin seed coat due to thinner palisade and parenchyma layers with fewer pectic polysaccharides and less protein, low percentage of fibre, owl's head shape and mostly smooth testa textured. They have large leaves, usually semi-spreading to semi-spreading growth habit, no anthocyanin with white flower colour. *Kabuli* seeds are normally cooked and consumed as whole and used as salads and vegetable mixes. *Kabuli* type covers 15 % of the world chickpea and grown mostly in Mediterranean regions, West Asia, North Africa and North America (Gaur *et al.*, 2008).

2.4. Production of Chickpea

The major contribution (almost 86.73 %) of the world production of chickpea is from Asia, with only 5 % coming from Africa. According FAOSTAT (2012) the world area under chickpea cultivation is 13.2 million hectares, with a total production of 11.6 million tons. The main chickpea producing countries are India, accounting for 67.68 % (7.5 million hectares), and 66.91 % (6.54 million ton) of production followed by Pakistan with 9.75 % (1.08 million hectares and 0.741 million ton (FAOSTAT, 2009). Other chickpea producing countries are Iran, Turkey, Myanmar, Australia, Ethiopia, Canada, Mexico, Syria, USA, Spain, Tanzania and Eritrea.

The annual production in Africa is approximately 430,000 tons. According to Mulwa *et al.* (2010), the main chickpea producer in Africa is Ethiopia (168,000 tons) with 39 % of the total production followed by Tanzania (63,000 tons) and Kenya (55,000 tons).

2.5. Constraints of Chickpea Production

The major bottlenecks limiting chickpea production and causing wide yield gap globally include biotic (Pod borer, Fusarium wilt, and Ascochyta blight) and abiotic (drought, heat, cold and salinity) (Millan *et al.,* 2006, Upadhyaya *et al.*, 2008) stresses. Ryan (1997) reported that the estimated collective yield losses due to abiotic stresses (6.4 million ton) were higher than those biotic stresses (4.8 million ton), which together cause annual yield loss of US$ 4.4 billion. In chickpea, biotic and abiotic constraints could be estimated by yield gap between the potential and actual yield.

Drought stress is the most important abiotic constraint of chickpea production, accounting for more than 50% yield reduction globally (Gaur *et al*., 2012).Thus the main attributes of the overall challenges could be low genetic variation of chickpea varieties which hindered the progress in chickpea genetic improvement (Malik *et al*, 2014). In addition Gaur *et al*. (2012) reported that another major constraint which hinders chickpea germplasm utilization has been lack of information on major agronomic and yield traits.

2.6. Phenology of Chickpea

Phenology is one of the quantitative parameters that plays critical role for adaptation of crops, including chickpea, to the soil and climatic conditions. Khan, Farhatullah and Khan (2011) reported substantial variation on days to flowering and maturity among chickpea genotypes. Normally short growth duration gives low yields in comparison to medium and long growth. This is due to the fact that longer growth period allows full utility of available soil moisture and nutrients and enables the plant to convert them into ultimate yields. In chickpea, Namvar and Sharifi (2011) reported that high biomass and yield production was obtained from late maturing genotypes compared to the short maturing types. However, early maturing varieties are preferred by farmers because they give more stable yield than late maturing (Gaur *et al*., 2008). Earliness trait helps the varieties to escape abiotic (terminal drought, cold and salinity) and biotic (diseases and insect pests) stresses which collectively occur late in the season.

Generally, phenology varies with cultivar, photoperiod, temperature, soil water and nutrient status. Flowering and podding are critical reproductive stages in chickpea development because extreme environmental conditions during these stages could have a major impact on pod filling, maturity and hence final yield. In chickpea, Upadhyaya *et al*. (2006) recommended identification of early traits along with large-seeded superior agronomic and yield traits that would prompt breeders to use them in further improvement programmes. In winter bread wheat, Egesel and Kahriman

(2013) reported that early flowering and maturing genotypes performed better in drought stress than late flowering and maturing genotypes and suggested that earliness criteria of selection for selecting suitable varieties for drought prone areas.

2.7. Phenotypic Variation of Traits

Variation is the occurrence of differences among individuals due to their genetic makeup and the environment in which they raised. Plant breeders are mostly interested in genetic variation since proper management of such variation could result in remarkable impact in the performance of the crop. Knowledge in variation among yield components is crucial in order to advance rapid and efficient crop improvement programme. Previous studies in chickpea have reported a significant variation for days to flowering, days to maturity, number of pods plant $^{-1}$ and seed yield (Bakhsh *et al*., 2003). Upadhyaya *et al.* (2002) reported significantly high variations for morphological, agronomic and yield traits in chickpea core collection. In other legumes, Roy *et al.* (2013) reported significant differences for days to flowering, days to maturity, number of branches plant $^{-1}$,number of pods plant $^{-1}$, number of seeds pod $^{-1}$, 100-seed weight and seed yield except plant height in lentil, number of pods plant -$^{-1}$, seed yield and drought tolerance in cowpea (Hegde & Mishra, 2009).

A genotype by environment interaction is a change in the relative performance of characters of two or more genotypes measured in two or more environments. Plant breeders usually conduct multi-locational evaluation before releasing varieties to farmers. High and stable yield is one of the prime goals of plant breeding, so multi locational data are used mostly to determine the relative performance of evaluated genotypes across environments. In chickpea, Bakhsh *et al.* (2003) reported that most previous studies conducted on different genotypes planted in different environments showed that most variations could be attributed either to genotypes or environments but not to genotype by environment interactions. In chickpea, Kan *et al*. (2010) reported significant genotype by environment interactions and identified high yielding and stable cultivars. In other crops, Mohamed (2013) reported significant genotype (9.5 %) and genotype by environment interactions (15.5 %) and the environmental effect explained 75 % of the total variation for grain yield in wheat. Underutilization of germplasm in chickpea improvement could be due to lack of information on yield and yield component traits which require replicated multi-location evaluation.

2.8. Germplasm Characterization and Evaluation

Crop genetic resources are important basis for global food security. They include genetic materials such as traditional varieties, modern cultivars, breeding lines, wild and wild relatives. Farshadfar and Farshadfar (2008) reported that diverse crop genetic resources are essential to meet the need for more and nutritious food. Improvement in any plant breeding programmes greatly relies on the extent of genetic variation available in their germplasm. Chickpea germplasm plays crucial role in generating new varieties having desired traits that boost production and enhancing resistance to biotic and abiotic stress or improve quality. Germplasm characterization and evaluation can provide useful information to plant breeders, agronomist and other scientists that are essential for better utilization of crop genetic resources. Malik *et al.* (2009) reported highly significant differences for number of secondary branches plant $^{-1}$, number of pods plant $^{-1}$, biomass yield, seed yield, 100 seed weight and harvest index in chickpea. Previous studies in chickpea, recommended that further evaluation of germplasm should be considered for traits like days to flowering and seed yield (Upadhyaya *et al*., 2002), plant height, number of primary and number of secondary branches plant $^{-1}$ (Ali *et al.*, 2008) to be used as selection criteria for yield improvement.

Evaluation of genetic variation in chickpea germplasm is indispensable for effective selection in genetic improvement of agronomic and yield traits. Earlier studies in chickpea have reported substantial genetic variation for days to flowering, days to maturity, plant height, number of primary and secondary branches plant $^{-1}$, biomass yield, growth habit, seed shape and seed colour (Qureshi *et al*., 2004), plant height, number of primary and secondary branches plant $^{-1}$, number of pods plant $^{-1}$ and biomass yield (Aslamshad *et al*., 2009).

2.9. Association of Yield and Other Agronomic Traits

Investigation of agronomic, yield and yield components provide a fundamental framework for identifying potentially useful characters in chickpea improvement programme. Most plant breeders are interested in maximizing selection efficiency that facilitates the identification of elite genotypes. Information on correlation among yield and yield related traits is the basis for indirect selection and development of improved varieties. Estimation of correlation coefficient is useful in planning future breeding and provides a measure of association among traits and with the targeted traits and hence could be useful as selection index.

Previous studies in chickpea have reported positive and highly significant correlation of seed yield with number of secondary branches plant $^{-1}$, plant height, number of pods plant $^{-1}$ and negatively significant with days to flowering, days to maturity and 100-seed weight (Ali & Ahsan, 2012), seed yield with biomass yield and number of secondary branches plant $^{-1}$ but negatively correlated with 100 seed weight (Malik *et al*., 2010) and suggested positively correlated traits could be used for indirect selection of yield for further chickpea improvement.

In other legumes, earlier studies had reported positive and highly significant correlation of seed yield with biomass yield, number of pods plant $^{-1}$ and plant height, and negatively correlated with days to flowering (Al-Ghzawi *et al.*, 2011), seed yield with number of seeds pod $^{-1}$, 100 seed weight, number of pods plant $^{-1}$, pod length, days to flowering and days to maturity (Okonkwo & Idahosa, 2013) in lentil and soybean respectively. Aghili *et al*. (2012) reported positive and highly significant correlation of seed yield with plant height, number of pods plant $^{-1}$, number of seeds pod $^{-1}$, biomass and 100 seed weight in lentil.

Studies on correlation among agronomic characters and with seed yield traits can supply more reliable information on the nature and level of interrelationships of chickpea yield with its related traits. Thus identification and exploitation of traits positively attributing to seed yield is essential as it enhances breeding efficiency of chickpea.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Site Description

The field experiments were conducted at two sites for two seasons. The two sites were Jomo Kenyatta University of Agriculture and Technology (JKUAT), Juja and University of Nairobi (UON) research station, Kabete while the two seasons were the long and short rain season of 2013. Juja is situated 36 km North East of Nairobi, along Nairobi-Thika highway. Juja lies at a latitude of 1 ^{o}11´ 0 ´´S, 37 ^{o} 7´ 0 ´´E with an altitude of 1530 metre above sea level and is in upper midland zone 4 which is semi-humid to semi-arid. Juja receives an annual rainfall range from 600 - 800 mm and mean annual temperature of 18.9 ^{o} C (Kaluli *et al.*, 2011). The soils have a pH range of 6.6 -7.65 (Batjes, 2006). Kabete is situated about 15 km to the West of Nairobi and lies at a latitude of 1 °15 ' S, longitude 36 ° 41' E with an altitude of 1940 metre above sea level and categorized in upper midland under agro-ecological zone 3 (marginal coffee zone) (Sombroek *et al.*,1982). Its climate is typically semi - humid with mean annual rainfall of 1000 mm and mean annual temperature of 18 ^{o} C. The soil is characterized as deep, well-drained and friable reddish or brown, friable clay (Karuku *et al*., 2012). Both experimental sites have bimodal rainfall pattern with peaks in April (long rain season) and November (short rain season).

3.2. Plant Materials

The chickpea genotypes used in the current study were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) gene bank, Nairobi and are part of the reference set of world core collection that has been identified for characterization and dissemination in the Eastern and Southern Africa region. They included ninety five genotypes (58 *desi* type and 37 *kabuli* type) of different countries of origin plus two check varieties of each type (Table 3.2 and 3.3). The checks are varieties that have been released in the Eastern Africa region. The important attributed of the check varieties are given in table 3.1.

Table 3.1: Chickpea Varieties Released in Eastern Africa

Varieties	Type	Year	Country	On farm yield (kg/ha)	Specific characteristics/ traits
ICCV 92318	*Kabuli*	2011	Tanzania	1192	Early to medium duration (87 days), medium seed size (33g/100 seeds), resistant to ,*Fusarium wilt* disease, attainable yield potential of 3.0 tons ha^{-1}
ICCV 00305	*Kabuli*	2009	Kenya/Tanzania	1800	Medium duration (90 days), medium seed size (36g/ 100 seeds), resistant to *Fusarium wilt* disease, attainable yield potential of 2.8 tons ha^{-1}
ICCV 00108	*Desi*	2009	Kenya/Tanzania	2030	Early to medium duration (86 days), resistant to *Fusarium wilt* disease, yield potential of 2.5 tons ha^{-1} ,grows well under residual moisture in clay soils
ICCV 97105	*Desi*	2010	Kenya/Tanzania	2400	Medium duration (92 days), medium seed size 34.5g/100 seeds, most preferred by farmers for number of pods plant -1, resistant to *Fusarium wilt* disease, yield potential of 2.2 – 3.0 tons ha^{-1}

Source (ICRISAT, 2013)

Table 3.2: *Desi* Chickpea Genotypes used in this Study and their Countries of Origin

Entry	Name	Origin	Entry	Name	Origin	Entry	Name	Origin
1	Annigeri	India	21	ICC 6294	Iran	41	ICC 6877	Iran
2	ICC 1052	Pakistan	22	ICC 15614	Tanzania	42	ICC 7326	Unknown
3	ICC 10685	Turkey	23	ICC 16261	Malawi	43	ICC 7413	India
4	ICC 11198	India	24	ICC 16524	Pakistan	44	ICC 7867	Iran
5	ICC 1164	Nigeria	25	ICC 16915	India	45	ICC 791	India
6	ICC 11903	Germany	26	ICC 1715	India	46	ICC 8318	India
7	ICC 11944	Nepal	27	ICC 2242	India	47	ICC 8522	Italy
8	ICC 12851	Ethiopia	28	ICC 2580	Iran	48	ICC 9002	Iran
9	ICC 12928	India	29	ICC 3325	Cyprus	49	ICC 9636	Afghanistan
10	ICC 13124	India	30	ICC 4093	Iran	50	ICC 9702	Afghanistan
11	ICC 1356	India	31	ICC 4182	Iran	51	ICC 9712	Afghanistan
12	ICC 1392	India	32	ICC 4463	Iran	52	ICC 9862	Afghanistan
13	ICC 1397	India	33	ICC 4657	India	53	ICC 9872	Afghanistan
14	ICC 8200	Iran	34	ICC 4872	India	54	ICC 9895	Afghanistan
15	ICC 1398	India	35	ICC 4991	India	55	ICCV 07102	ICRISAT, India
16	ICC 4918	India	36	ICC 506	India	56	ICCV 00108 (check)	ICRISAT, Kenya
17	ICC 14051	Ethiopia	37	ICC 5504	Mexico	57	ICCV 07111	ICRISAT, India
18	ICC 1422	India	38	ICC 5613	India	58	ICCV 10	ICRISAT, India
19	ICC 14815	India	39	ICC 5639	India	59	ICCV 00104	ICRISAT, India
20	ICC 1510	India	40	ICC 6579	Iran	60	ICCV 97105 (check)	ICRISAT, Kenya

Table 3.3: ***Kabuli*** **Chickpea Genotypes used in this Study and their Countries of Origin**

Entry	Name	Origin	Entry	Name	Origin
1	ICC 10885	Ethiopia	21	ICCV 08302	ICRISAT, India
2	ICC 13283	Iran	22	ICCV 08303	ICRISAT, India
3	ICC 13357	Iran	23	ICCV 08307	ICRISAT, India
4	ICC 13461	Iran	24	ICCV 92311	ICRISAT, India
5	ICC 13764	Iran	25	ICCV 08310	ICRISAT, India
6	ICC 15802	Syria	26	ICCV 92318 (Check)	ICRISAT, Kenya
7	ICC 16654	China	27	ICCV 95311	ICRISAT, India
8	ICC 2482	Iran	28	IG 71055	ICRISAT, India
9	ICC 7315	Iran	29	ICCV 07304	ICRISAT, India
10	ICCV 00302	ICRISAT, India	30	IG 72109	ICRISAT, India
11	ICCV 00305 (check)	ICRISAT, Kenya	31	K017	ICRISAT, India
12	ICCV 00402	ICRISAT, India	32	K004	ICRISAT, India
13	ICCV 03309	ICRISAT , India	33	K012	ICRISAT, India
14	ICCV 03404	ICRISAT, India	34	K022	ICRISAT, India
15	ICCV 05312	ICRISAT, India	35	K025	ICRISAT, India
16	ICCV 05315	ICRISAT, India	36	ICCV 08313	ICRISAT, India
17	ICCV 07306	ICRISAT, India	37	K038	ICRISAT, India
18	ICCV 06304	ICRISAT, India	38	K041	ICRISAT, India
19	ICCV 07308	ICRISAT, India	39	K034	ICRISAT, India
20	ICCV 07313	ICRISAT, India			

3.3. Experimental Design

The *desi* and *kabuli* types were treated as different experiments. For each type the design of the experiment was alpha lattice with three replications. Each experimental plot comprised of two rows of 2.5 metre length and 1 metre width and a gross and net plot areas of 2.5 m^2 and 2.3 m^2 respectively. Genotypes were randomly assigned to entire plots in each block with in the replication. All genotypes were sown in two rows with inter row spacing of 50 cm.

3.4. Land Preparation and Planting at the Two Sites

Kabete: the experimental field at Kabete research site was disc ploughed and disc harrowed. In addition each plot was manually leveled with the help of a spade and forked jembe. Seeds of all genotypes were planted by hand drilling on 15th May 2013 for season I and 18th November 2013 for season II.

Juja: the experimental field at Juja was dug manually two times to a fine tillth. Each plot was leveled with the help of a spade and forked jembe. Seeds of all genotypes were sown by hand drilling on 28th May 2013 for season I and 29th December 2013, season II. Two weeks after emergence, plants were thinned to maintain intra-row spacing of 10 cm at each site and season.

The experiments were rain-fed and supplementary irrigation was provided when necessary. The experimental plots were maintained weed free by manual weeding during the growing period. All the cultural practices were performed as recommended for chickpea production at both sites and seasons.

3.5. Data Collection

Data on various agro-morphological traits were recorded during growth based on the available descriptors for chickpea (*Cicer arientinum* L.) (IBPGR, ICRISAT & ICARDA, 1993) Both qualitative and quantitative data were collected using the descriptors. Data on flower colour, stem colour, growth habit, pod dehiscence and leaf type were scored on plot $^{-1}$ basis while seed coat colour, seed shape and seed testa texture were scored visually on seed samples. Data on days to 50 % flowering, days to 50 % podding, days to 75 % maturity, pod filling period, biomass yield ha $^{-1}$ and seed yield ha $^{-1}$were recorded on plot $^{-1}$ basis while other characters were recorded on six randomly selected and pre-tagged plants from the middle two rows of each plot.

The main variables recorded were as follows:

Days to 50 % Flowering (DF): Number of days from emergence to the time when 50 % of the plants in the plots produced at least one open flower.

Flower Colour (FC): This parameter was scored visually as per the descriptors. The data were categorized using scale like 3 - when the flower colour was dark pink, 4 - when the flower colour was light pink and 6 - when it was white.

Stem Colour (SC): It was scored visually during the peak growth stage and classified based on descriptors. A scale was given, 1 - when the stem was light green, 2 - when the stem was green (dark green), 3 - when the colour was partly purple, 4 - when the colour was predominantly purple and 5 - when the stem colour was highly purple.

Growth Habit (GH): The angle of primary branches from the vertical axis was recorded at the mid pod filling stage and classified as (1- Erect (0 - 15^o), 2 - semi-erect (16 - 25^o), 3-semi spreading (26 - 60^o), 4 - spreading (61- 80^o) and 5 - prostrate using descriptors.

Plant Canopy Width (PCW): The diameter of the plant was measured using a ruler in centimeter during peak pod filling period on six randomly selected and pre tagged plants plot $^{-1}$ and recorded as plant canopy width plant $^{-1}$.

Plant Height (PH): The height (cm) of the main stem was measured from the ground level to the tip of the plant using a ruler at 75 % physiological maturity.

Number of Primary Branches (NPB): The total number of branches originating from the main stem which gives rise to secondary branches was counted at 75% physiological maturity.

Number of Secondary Branches (NSB): The total number of branches which rise from primary branches was counted at 75 % physiological maturity.

Leaf Type (LT): It was scored at flowering as plot $^{-1}$ basis and given 1, 2 and 3 when the leaf type was normal (uni-imparipinnate), simple, multipinnate respectively**.**

Number of Leaflet Leaf $^{-1}$ (NLLF $^{-1}$ /NLLP $^{-1}$): It was recorded at two critical stages such as flowering (appendix ii) and podding stages using scales: 1,2,3,4 and 5 when number of leaflets ranged from 5 - 7, 7 - 9, 9 - 11, 11 - 13 and greater than 13 respectively.

Days to 50 % Podding (DP): Number of days taken from emergence to time when 50 % of plants in the plot produced at least one pod (appendix ii).

Pod Filling Period (PFP): Number of days from 50 % flowering to the time when 75 % the plants in the plot reached physiological maturity.

Days to 75 % Maturity (DM): Number of days from emergence to the time when 75 % of the plants in the plot reached 75 % physiological maturity.

Pod Dehiscence (PD): This data was recorded at maturity in percent and given a scale of 0 when no pod dehiscence, 1- pod dehiscence (< 10 %) and 2 pod dehiscence (> 10 %).

Pod Length (PL): It was recorded at maturity by measuring ten pods each from six randomly selected and pre-marked plants using a ruler and recorded as plant $^{-1}$ and the length grouped as 3 = short (< 15 mm), 5 = medium (15 – 20 mm) and 7 = long (> 20 mm).

Number of Pods Plant $^{-1}$ (NPP $^{-1}$): The total number of pods plant $^{-1}$ were counted on six randomly selected and pre-marked plants and recorded as number of pods plant $^{-1}$.

Number of Seeds Pod $^{-1}$ (NSP $^{-1}$): The total number of seeds pod $^{-1}$ were counted in ten pods each from six randomly selected plants and average seeds pod $^{-1}$ was computed.

Seed Coat Colour (SCC): It was scored visually after threshing and winnowing and classified as black, dark brown, brown, light brown, ivory white, green and light yellow.

Seed Shape (SS): It was scored visually based on the descriptors and classified as angular (ram's head), irregular rounded (owl's head) and pea shaped (smooth round).

Seed Testa Texture (ST): It was scored visually based on the descriptors and classified by given a scale 3 = rough, 5 = smooth and 7 = tuberculated testa textures.

Total Biomass (BM) : The total weight of above ground biomass was weighed using electronic balance (in g or kg net plot $^{-1}$) and converted into kilogram ha $^{-1}$.

Seed Yield (SY): This parameter was taken after harvesting, threshing and winnowing (in g or kg net plot $^{-1}$). The seed yield was weighed using electronic balance net plot $^{-1}$ basis and converted into kilo gram ha $^{-1}$ for each genotype in three replications.

Hundred Seed Weight (HSW): Hundred seeds were counted in triplicate and weighed using electronic balance and recorded in gram plot $^{-1}$of each genotype in three replications.

Harvest Index (HI): Calculated as the ratio of seed yield to biomass yield in percent

3.6. Data Analysis

3.6.1. Statistical Analysis

Data on variation were analysed using SAS mixed procedure (SAS Institute Inc., second edition, 2013) and correlation coefficient using Gen-Stat (Gen-Stat release 15.1, 2014) at 5 % level of significance. The qualitative data were analysed using descriptive statistics such as frequency and percentage while the quantitative data were analysed based on descriptive statistics including mean, range, standard error, variance and coefficient of variation.

Correlation analyses among the mean values of quantitative traits were conducted as outlined by Kwon and Torrie, (1964) to determine the association among agronomic traits and with seed yield.

CHAPTER FOUR

4.0. RESULTS

The information on metrological data at Kabete and Juja in the long and short rain seasons are presented in Appendix 1. The average rainfall, maximum and minimum temperatures in the long and short rain seasons at Kabete were 123.5 mm , 21.0 ^{o}C and 11.8 ^{o}C and 92.9 mm, 25.1^{o} C and 14.0 ^{o}C respectively (appendix 1). While at Juja the average rainfall, maximum and minimum temperatures in the long and short rain seasons were 85.0 mm , 26.1 ^{o}C and 13.9 ^{o}C and 75.0 mm, 28 ^{o}C and 14.5 ^{o}C respectively.

4.1. Genetic Evaluation of *Desi* Chickpea Genotypes

4.1.1. Agronomic Traits

Day to 50 % Flowering

The genotypes and genotype by environment interactions showed highly significant ($p < 0.0001$) variation in their response to flowering (Table 4.1). All genotypes took longer time to flower in long rains compared to short rains at both sites (Table 4.1). Early flowering (ICC 1356, ICC 16915 and ICC 15614) and late flowering (ICC 791, ICC 12928, ICC 11944 and ICC 2242) genotypes at Juja also flowered early and late at Kabete. The ranking of genotypes for days to flowering varied across environments. Twenty two and twenty one genotypes flowered earlier than the check varieties ICCV 00108 and ICCV 97105 respectively.

The results further indicated that on the basis of overall means, thirteen genotypes could be classified as early (< 50 days), 17 genotypes as moderate (50 – 55 days) and 17 genotypes as late (55 – 60 days) and 13 very late (> 60 days). The earliest flowering genotypes were ICC 8318 (46. 0 days) and ICC 1398 (46.0 days) followed by ICC 506 (46.0 days), ICC 16915 (47.0 days) and ICCV 10 (47.0 days). Genotypes ICC 12928 (71.0days) and ICC 791 (71.0 days) followed by ICC 11944 (68.0 days), ICC 11903 (67.0 days) and ICC 2242 (66.0 days) were the latest in flowering. The check varieties ICCV 97105 (53.0days) and ICCV 00108 (53.0 days) were categorized as moderate in flowering time.

Based on the environment wise means, the earliest flowering was recorded in short rain season Kabete (48.0 days) followed by short rain season Juja (51.0 days), long rain season Kabete (62.0 days) and long rain season Juja (63.0 days) with a grand mean of 56.0 days.

Number of Leaflet Leaf $^{-1}$ at Podding

There were highly significant (< 0.0001) differences among genotypes and genotype by environment interactions for number of leaflet leaf $^{-1}$ at podding (Table 4.1). Genotypes recorded the highest number of leaflet leaf $^{-1}$ at podding during short rains compared to long rains at both sites. Genotypes with the highest number of leaflet leaf $^{-1}$ at Juja were (ICC 9636, ICC 1422, ICC 1510, ICCV 07111 and ICC 5639) also recorded the highest at Kabete. Genotypes (ICC 10685, ICC 9862 and ICC 14815) that recorded the lowest leaflet leaf $^{-1}$ during podding at Kabete recorded the lowest as well at Juja. Thirty six and forty one genotypes exceeded the check varieties ICCV 00108 and ICCV 97105 for number of leaflet leaf $^{-1}$ at podding respectively.

Genotypes varied with respect to overall means for number of leaflet leaf $^{-1}$ at podding. Four genotypes were classified as low (< 13.5), 22 genotypes as moderate (13.5 – 14.0) and 34 genotypes had high (> 14.0) which indicated a wide variation among genotypes. Genotypes with the highest number of leaflet leaf $^{-1}$ at podding were ICC 9636 (16.9) and ICC 1422 (15.8) followed by ICC 1510 (15.5), ICCV 07111 (15.5) and ICC 5639 (15.1). While the lowest number of leaflet leaf $^{-1}$ at podding was recorded in genotypes ICC 10685 (12.7), ICC 9872 (13.2), ICC 9895 (13.4) and ICC 8522 (13.5). The check varieties ICCV 00108 (13.9) and ICCV 97105 (13.8) were classified as moderate for number of leaflet leaf $^{-1}$ at podding. With respect to environment wise means, the highest number of leaflet leaf $^{-1}$ at podding was recorded during short rain season at Juja (14.6) followed by long rain season at Juja (14.2) short rain season at Kabete (14.2) and in long rain season at Kabete (13.6) with a grand mean of 14.2

Table 4.1: Variation among *Desi* Genotypes for Days to Flowering and Number of leaflet leaf $^{-1}$ at Podding at Juja and Kabete

	Days to 50 % Flowering					Number of leaflet leaf $^{-1}$ at Podding					
	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Pr.
ICC 9636	65.7±3.0	53.8±1.0	77.0±3.2	55.0±0.9	62.9	17.1±0.2	17.3±0.3	16.2±0.3	17.1±0.3	16.9	**
ICCV 97105 (Check)	56.4±3.0	49.0±1.0	59.4±3.2	47.0±0.9	52.9	13.7±0.2	14.1±0.3	13.4±0.3	14.0±0.3	13.8	**
ICCV 00108 (Check)	59.3±3.0	49.0±1.0	54.0±3.2	49.9±0.9	53.0	13.9±0.2	14.3±0.3	13.5±0.3	13.8±0.3	13.9	**
ICC 6579	59.3±3.0	53.2±1.0	55.5±3.2	49.6±0.9	54.4	14.0±0.2	14.4±0.3	13.2±0.3	14.0±0.3	13.9	**
ICC 5639	66.9±3.0	58.9±1.0	69.6±3.2	53.4±0.9	62.2	15.3±0.2	15.5±0.3	14.6±0.3	14.8±0.3	15.1	**
ICC 1052	64.8±3.0	47.1+1.0	54.0±3.7	51.5±0.9	54.4	13.9±0.2	14.2±0.3	13.2±0.3	13.5±0.3	13.7	**
ICC 15614	51.5±3.0	48.8±1.0	53.5±3.2	42.0±0.9	49.0	14.7±0.2	15.4±0.3	14.7±0.3	15.0±0.3	14.9	**
ICC 3325	53.5±3.0	47.0±1.0	57.4±3.2	44.3±0.9	50.5	13.8±0.2	13.8±0.3	13.3±0.3	13.8±0.3	13.7	**
ICC 16915	51.3±3.0	38.5±1.0	54.1±3.2	43.2±0.9	46.8	13.6±0.2	14.4±0.3	13.1±0.3	13.6±0.3	13.7	**
ICC 4182	63.6±3.0	44.8±1.0	56.2±3.2	48.6±0.9	53.3	14.4±0.2	14.8±0.3	13.7±0.3	14.2±0.3	14.3	**
ICC 7867	69.8±3.0	55.6±1.0	62.9±3.2	51.4±0.9	59.9	13.8±0.2	14.3±0.3	13.0±0.3	13.9±0.3	13.8	**
ICC 1356	49.0±3.0	45.6±1.0	51.1±3.2	43.6±0.9	47.3	14.1±0.2	14.8±0.3	13.9±0.3	14.5±0.3	14.3	**
ICC 1422	51.7±3.0	43.4±1.0	53.1±3.7	44.9±0.9	48.3	15.9±0.2	16.3±0.3	15.1±0.3	15.8±0.3	15.8	**
ICC 4093	61.3±3.0	48.4±1.0	55.6±3.2	49.2±0.9	53.6	13.9±0.2	14.4±0.3	13.2±0.3	13.8±0.3	13.8	**
ICC 16261	69.3±3.0	55.9±1.0	67.1±3.2	46.9±0.9	59.8	14.0±0.2	14.7±0.3	13.6±0.3	13.9±0.3	14.0	**
ICC 1715	64.9±3.0	56.2±1.0	68.0±3.7	50.4±0.9	59.9	14.8±0.2	14.9±0.3	13.9±0.3	14.7±0.3	14.6	**
ICC 8318	51.2±3.0	44.2±1.0	45.5±3.2	42.2±0.9	45.8	14.0±0.2	14.4±0.3	13.6±0.3	14.0±0.3	14.0	**
ICC 2580	55.3±3.0	44.4±1.0	52.5±3.2	44.0±0.9	49.0	13.8±0.2	14.3±0.3	13.3±0.3	14.1±0.3	13.8	**
ICC 16524	52.9±3.0	45.1±1.0	61.8±3.2	44.3±0.9	51.0	13.9±0.2	14.1±0.3	12.9±0.3	13.8±0.3	13.6	**
ICC 4463	71.3±3.0	54.9±1.0	59.8±3.2	49.4±0.9	58.9	14.2±0.2	15.4±0.3	13.8±0.3	14.3±0.3	14.4	**
ICC 1392	59.1±3.0	42.5±1.0	57.2±3.2	46.6±0.9	51.4	14.4±0.2	14.7±0.3	13.8±0.3	14.6±0.3	14.4	**
ICC 5504	68.4±3.0	57.5±1.0	59.4±3.2	47.8±0.9	58.3	13.9±0.2	14.5±0.3	13.3±0.3	14.0±0.3	13.9	**
ICC 9872	62.8±3.0	42.9±1.0	57.8±3.7	47.3±0.9	52.7	13.1±0.2	13.6±0.3	12.7±0.3	13.4±0.3	13.2	**
ICC 2242	72.5±3.0	60.0±1.0	81.2±3.2	50.9±0.9	66.1	14.5±0.2	14.6±0.3	13.3±0.3	14.2±0.3	14.1	**
ICC 1510	67.9±3.0	59.2±1.0	72.7±3.2	53.4±0.9	63.3	15.5±0.2	15.8±0.3	14.9±0.3	15.7±0.3	15.5	**
ICC 12928	74.3±3.0	60.8±1.0	85.4±3.2	62.6±0.9	70.8	15.0±0.2	15.0±0.3	13.9±0.3	14.5±0.3	14.6	**
Annigeri©	62.3±8.2	50.7±8.2	61.4±8.2	48.4±8.2	55.7	14.2±0.8	14.6±0.8	13.6±0.8	14.2±0.8	14.2	**
ICC 8200©	62.3±8.2	50.7±8.2	61.4±8.2	48.4±8.2	55.7	14.2±0.8	14.6±0.8	13.6±0.8	14.2±0.8	14.2	**
ICC 4918©	62.3±8.2	50.7±8.2	61.4±8.2	48.4±8.2	55.7	14.2±0.8	14.6±0.8	13.6±0.8	14.2±0.8	14.2	**
ICC 6294©	62.3±8.2	50.7±8.2	61.4±8.2	48.4±8.2	55.7	14.2±0.8	14.6±0.8	13.6±0.3	14.2±0.8	14.2	**
ICCV 07102©	62.3±8.2	50.7±8.2	61.4±8.2	48.4±8.2	55.7	14.2±0.8	14.6±0.8	13.6±0.8	14.2±0.8	14.2	**

Continue Table 4.1

ICCV 00104©	62.3±8.2	50.7±8.2	61.4±8.2	48.4±8.2	55.7	14.2±0.2	14.6±0.8	13.6±0.8	14.2±0.8	14.2	**
ICC 10685	57.8±3.0	48±1.0	53.2±3.7	40.8±0.9	49.9	12.7±0.2	13.0±0.3	11.9±0.3	13.1±0.3	12.7	**
ICC 7413	58.1±3.5	49.8±1.0	49.7±3.2	43.7±0.9	50.3	13.7±0.2	14.5±0.3	13.3±0.3	13.8±0.3	13.8	**
ICCV 10	57.6±3.0	34.7±1.0	53.3±3.2	42.3±0.9	47.0	14.0±0.2	14.3±0.3	13.3±0.3	14.0±0.3	13.9	**
ICC 7326	67.4±3.0	58.8±1.0	60.4±3.2	51.0±0.9	59.4	14.1±0.2	14.9±0.3	13.7±0.3	14.1±0.3	14.2	**
ICC 9712	64.5±3.0	57.4±1.0	59.5±3.2	49.4±0.9	57.7	14.3±0.2	14.7±0.3	13.6±0.3	13.8±0.3	14.1	**
ICC 14815	62.8±3.0	53.9±1.0	59.7±3.2	49.3±0.9	56.4	13.8±0.2	13.8±0.3	13.1±0.3	13.5±0.3	13.5	**
ICC 4657	70.2±3.0	53.4±1.0	71.2±3.2	50.8±0.9	61.4	14.0±0.2	14.2±0.3	13.3±0.3	13.9±0.3	13.8	**
ICC 1164	63.4±3.0	55.8±1.0	62.1±3.2	47.7±0.9	57.3	15.0±0.2	15.1±0.3	14.2±0.3	14.8±0.3	14.8	**
ICC 14051	50.9±3.0	38.6±1.0	56.8±3.2	48.5±0.9	48.7	14.0±0.2	14.5±0.3	13.5±0.3	14.4±0.3	14.1	**
ICC 12851	58.0±3.0	45.8±1.0	57.8±3.2	50.8±0.9	53.1	14.2±0.2	14.6±0.3	13.5±0.3	14.0±0.3	14.1	**
ICC 4991	56.5±3.0	54.4±1.0	59.1±3.2	43.1±0.9	53.3	13.9±0.2	15.0±0.3	13.8±0.3	14.4±0.3	14.3	**
ICC 506	52.3±3.0	38.2±1.0	48.5±3.2	46.4±0.9	46.3	14.1±0.2	14.4±0.3	13.6±0.3	14.1±0.3	14.0	**
ICC 9702	71.8±3.0	59.8±1.0	59.7±3.7	54.0±0.9	61.3	14.4±0.2	14.6±0.3	13.5±0.3	14.0±0.3	14.1	**
ICCV 07111	64.5±3.0	40.2±1.0	55.0±3.2	41.1±0.9	50.2	15.3±0.2	15.9±0.3	14.6±0.3	16.0±0.3	15.5	**
ICC 1398	57.3±3.0	34.7±1.0	49.4±3.2	42.2±0.9	45.9	14.4±0.2	14.7±0.3	13.6±0.3	14.3±0.3	14.3	**
ICC 13124	55.9±3.5	46.0±1.0	52.5±3.2	50.1±0.9	51.1	13.8±0.2	14.5±0.3	13.7±0.3	14.1±0.3	14.0	**
ICC 6877	71.0±3.0	55.2±1.0	76.5±3.7	60.2±0.9	65.7	15.0±0.2	14.6±0.3	13.9±0.3	14.3±0.3	14.4	**
ICC 4872	54.2±3.0	36.6±1.0	52.1±3.2	45.2±0.9	47.0	14.4±0.2	14.9±0.3	13.8±0.3	14.6±0.3	14.4	**
ICC 11198	68.4±3.0	57.0±1.0	75.9±3.2	49.8±0.9	62.8	13.8±0.2	13.8±0.3	12.9±0.3	13.7±0.3	13.6	**
ICC 5613	59.5±3.0	50.5±1.0	54.5±3.2	43.4±0.9	52.0	14.2±0.2	14.6±0.3	13.7±0.3	14.6±0.3	14.3	**
ICC 9895	67.2±3.5	55.2±1.0	56.7±3.7	49.0±0.9	57.0	13.5±0.2	14.0±0.3	12.6±0.3	13.3±0.3	13.4	**
ICC 11903	76.5±3.0	62.3±1.0	75.3±3.2	53.8±0.9	67.0	15.2±0.2	15.4±0.3	14.3±0.3	15.0±0.3	15.0	**
ICC 1397	70.0±3.5	59.3±1.0	78.2±3.7	47.6±0.9	63.9	14.0±0.2	14.3±0.3	13.1±0.3	14.0±0.3	13.8	**
ICC 8522	52.6±3.0	47.9±1.0	51.5±3.2	47.2±0.9	49.8	13.5±0.2	14.1±0.3	12.9±0.3	13.5±0.3	13.5	**
ICC 11944	73.4±3.0	60.4±1.0	80.9±3.2	56.4±0.9	67.8	14.8±0.2	14.8±0.3	13.6±0.3	14.1±0.3	14.3	**
ICC 9862	68.5±3.0	52.7±1.0	65.3±3.7	48.1±0.9	58.7	13.6±0.2	14.4±0.3	12.8±0.3	13.8±0.3	13.7	**
ICC 791	76.2±3.0	65.3±1.0	88.3±3.2	53.0±0.9	70.7	13.8±0.2	13.7±0.3	12.6±0.3	14.0±0.3	13.5	**
ICC 9002	64.1±3.0	57.9±1.0	73.0±3.7	49.1±0.9	61.0	14.2±0.2	14.4±0.3	13.1±0.3	13.9±0.3	13.9	**
Mean	62.3	50.7	61.4	48.4	55.7	14.2	14.6	13.6	14.2	14.2	
Minimum	49.0	34.7	45.5	40.8	45.8	12.7	13.0	11.9	13.1	12.7	
Maximum	76.5	65.3	88.3	62.6	70.8	17.1	17.3	16.2	17.1	16.9	

** -significant at 1 %, * - significant at 5 % and NS – non –significant at 5 % level of significant , ©- Genotypes were analysed using missing block and hence they have the same values for all traits, Pr- Probability value

Plant Canopy Width

Genotypes and genotype by environment interactions exhibited highly significant ($p < 0.0001$) variation for plant canopy width (Table 4.2).The evaluated genotypes recorded larger plant canopy width during long rains compared to short rains at both sites, except genotypes ICC 1356, ICC 4463, ICC 1510, ICC 12928, ICC 7326, ICC 9712, ICC 14815, ICC 14051, ICC 506, ICCV 07111, ICC 1398, ICC 13124, ICC 6877, ICC 4872, ICC 5613, ICC 9895, ICC 8522, ICC 11944, ICC 9862, ICC 791 and ICC 9002 which recorded larger plant canopy width in short rains at Kabete. The studied genotypes recorded larger plant canopy width at Juja compared to Kabete. Genotypes with larger (ICC 7867, ICC 9702, ICC 6877 and ICC 9895) and smaller (ICC 11194, ICC 791, ICCV 07111 and ICC 1398) plant canopy width at Juja also recorded larger and smaller at Kabete. The ranking of genotypes for plant canopy width varied across environments. Thirty three and 33 genotypes surpassed the check varieties ICCV 00108 and ICCV 97105 for plant canopy width respectively.

On the basis of overall means, the evaluated genotypes differed in plant canopy width and showed a wide variation. It indicated that 6 genotypes had small plant canopy width (< 60 cm), 34 genotypes had medium (60.0 – 70.0 cm) and 20 genotypes had large (> 70 cm) plant canopy width. Genotype ICC 9895 (85.8 cm) followed by ICC 11903 (84.5 cm), ICC 9702 (84.2 cm), ICC 7867 (83.9 cm) and ICC 6877 (83.8 cm) had the largest plant canopy width. The smallest plant canopy width was recorded in genotype ICC 11944 (50. 6 cm), ICCV 07111 (56.3 cm), ICC 1398 (57.4 cm), ICC 11198 (58.8 cm) and ICC 9002 (59.3 cm). Check varieties ICCV 00108 (66.5 cm) and ICCV 97105 (66.5 cm) were classified as moderate for plant canopy width. Based on environment wise means, the largest plant canopy width was recorded during long rains at Juja (83.0 cm) followed by short rains at Juja (69.2 cm), long rains (64.8 cm) and short rains at Kabete (64.8 cm) with a grand mean of 70.4 cm.

Pod Length

There were highly significant ($p < 0.0001$) variation among studied genotypes and genotype by environment interactions for pod length (Table 4.2). Genotypes recorded longer pod length during short rains compared to long rains at both sites. In addition, all genotypes recorded longer pod length during short rain season at Kabete compared to Juja. Genotypes with longer (ICC 7326, ICC 9872, ICC 6877 and ICC 7867) and shorter (ICC 11194, ICC 791, ICC 3325 and ICC 10685) pod length at Juja also recorded longer and shorter pod length at Kabete. The ranking of genotypes for pod length differed across environments except ICC 791 which consistently recorded shorter pod length. Nine and four genotypes surpassed the check varieties ICCV 00108 and ICCV 97105 for pod length respectively.

Genotypes differed with respect to overall means for pod length and based on the descriptors for chickpea, 38 genotypes were classified as short (< 15 mm) and 22 genotypes as medium (15 – 20 mm). Genotypes ICC 6877 (18.8 mm) and ICC 9872 (18.4) followed by ICC 7326 (18.1 mm), ICC 7867 (17.7 mm) and ICCV 97105 (17.4 mm) recorded the longest pod length. While genotypes ICC 791 (12.1 mm), ICC 11944 (12.8 mm), ICC 10685 (12.9 mm), ICC 1715 (12.9 mm) and ICC 3325 (512.9 mm) were recorded the shortest pod length. The check varieties ICCV 00108 (16.0 mm) and ICCV 97105 (17.4 mm) were classified as medium. With respect to environment wise means, the longest pod length among studied genotypes was recorded in short rain season at Kabete (17.1 mm) followed by short rain season Juja (15.3 mm), long rain season Juja (13.8 mm) and long rain season Kabete (13.0 mm) with a grand mean of 14.8 mm .

Table 4.2: Performance of *Desi* Genotypes for Plant Canopy Width and Pod Length at Juja and Kabete

	Plant Canopy Width in centimeters					Pod Length in millimeter					
Genotypes	Long rain Juja Mean±S.E	Short rain Juja Mean±S.E	Long rain Kabete Mean±S.E	Short rain Kabete Mean±S.E	Overall Mean	Long rain Juja Mean±S.E	Short rain Juja Mean±S.E	Long rain Kabete Mean±S.E	Short rain Kabete Mean±S.E	Overall Mean	Pr.
ICC 9636	85.3±4.7	59.9±3.6	64.4±5.5	63.6±4.1	66.4	14.7±0.7	17.0±0.6	13.9±0.7	18.1±0.6	15.9	**
ICCV 97105 (Check)	83.0±4.7	66.2±3.6	64.3±5.5	57.7+4.1	66.5	16.8±0.7	18.3±0.6	15.6±0.7	18.7±0.6	17.4	**
ICCV 00108 (Check)	82.9±4.7	60.1±3.6	66.7±5.5	61.4±4.1	66.5	14.9±0.7	16.6±0.6	14.6±0.7	18.0±0.6	16.0	**
ICC 6579	74.1±4.7	58.4±3.6	60.8±5.5	68.9±4.1	66.4	12.8±0.7	14.8±0.6	12.3±0.7	16.6±0.6	14.1	**
ICC 5639	84.4±4.7	64.2±3.6	64.2±5.5	58.9±4.1	66.2	13.2±0.7	14.0±0.6	12.4±0.7	16.7±0.6	14.1	**
ICC 1052	97.1±4.7	86.5±3.6	76.5±5.5	74.8+4.1	83.7	13.7±0.7	16.1±0.6	12.7±0.7	17.7±0.6	15.0	**
ICC 15614	77.2±4.7	59.0±3.6	62.4±5.5	50.0±4.1	62.3	11.8±0.7	13.6±0.6	11.4±0.7	15.6±0.6	13.1	**
ICC 3325	81.4±4.7	59.3±3.6	60.7±5.5	55.2±4.1	63.2	11.8±0.7	13.8±0.6	11.2±0.7	15.0±0.6	12.9	**
ICC 16915	90.0±4.7	78.4±3.6	77.3±5.5	72.0±4.1	76.3	14.7±0.7	16.0±0.6	14.0±0.7	18.4±0.6	15.8	**
ICC 4182	97.0±4.7	95.3±3.6	76.8±5.5	77.4±4.1	81.8	13.5±0.7	14.4±0.6	12.5±0.7	16.8±0.6	14.3	**
ICC 7867	104.2+4.7	100.8±3.6	79.6±5.5	77.5±4.1	83.9	16.6±0.7	19.7±0.6	15.0±0.7	19.4±0.6	17.7	**
ICC 1356	71.2±4.7	56.5±3.6	50.1±5.5	55.6±4.1	60.0	12.9±0.7	13.8±0.6	12.2±0.7	16.1±0.6	13.8	**
ICC 1422	78.6±4.7	63.1±3.6	63.2±5.5	62.4±4.1	66.6	14.8±0.7	15.3±0.6	14.0±0.7	17.0±0.6	15.3	**
ICC 4093	91.2±4.7	73.8±3.6	73.1±5.5	69.2±4.1	73.4	12.0±0.7	13.3±0.6	11.2±0.7	15.7±0.6	13.0	**
ICC 16261	81.8±4.7	64.9±3.6	66.6±5.5	63.9±4.1	68.3	13.7±0.7	15.1±0.6	12.9±0.7	16.0±0.6	14.4	**
ICC 1715	76.4±4.7	60.0±3.6	56.1±5.5	48.2±4.1	60.5	11.9±0.7	13.4±0.6	11.3±0.7	14.8±0.6	12.9	**
ICC 8318	86.1±4.7	59.9±3.6	75.1±5.5	71.5±4.1	71.0	13.5±0.7	14.9±0.6	13.2±0.7	17.5±0.6	14.8	**
ICC 2580	81.7±4.7	69.5±3.6	59.8±5.5	56.3±4.1	65.8	13.0±0.7	14.5±0.6	12.2±0.7	15.9±0.6	13.9	**
ICC 16524	68.7±4.7	54.7±3.6	55.8±5.5	53.9±4.1	60.5	12.4±0.7	13.7±0.6	11.5±0.7	15.8±0.6	13.4	**
ICC 4463	77.7±5.4	90.2±3.6	77.3±5.5	81.4±4.1	81.6	12.9±0.7	14.4±0.6	12.7±0.7	17.1±0.6	14.3	**
ICC 1392	81.0±4.7	66.8±3.6	60.4±5.5	52.8±4.1	64.4	14.5±0.7	15.4±0.6	14.0±0.7	17.3±0.6	15.3	**
ICC 5504	97.4±4.7	87.8±3.6	82.7±5.5	62.6±4.1	77.7	15.7±0.7	17.1±0.6	14.7±0.7	18.1±0.6	16.4	**
ICC 9872	102.2±4.7	87.7±3.6	88.0±5.5	81.2±4.1	83.7	17.7±0.7	19.6±0.6	15.9±0.7	20.4±0.6	18.4	**
ICC 2242	74.4±4.7	54.3±3.6	60.5±5.5	58.8±4.1	62.8	12.6±0.7	13.8±0.6	12.1±0.7	17.2±0.6	13.9	**
ICC 1510	74.4±4.7	69.7±3.6	53.0±5.5	62.6±4.1	65.7	14.2±0.7	17.3±0.6	13.8±0.7	17.2±0.6	15.6	**
ICC 12928	85.7±4.7	68.4±3.6	59.1±5.5	60.4±4.1	68.4	12.7±0.7	14.8±0.6	12.0±0.7	16.4±0.6	14.0	**
Annigeri©	83.0±13.3	69.2±13.3	64.8±13.0	64.8+13.3	70.4	13.8±1.7	15.3±1.7	13.0±1.7	17.1±1.7	14.8	**
ICC 8200©	83.0±13.3	69.2±13.3	64.8±13.3	64.8±13.3	69.1	13.8±1.7	15.3±1.7	13.0±1.7	17.1±1.7	14.8	**
ICC 4918©	83.0±13.3	69.2±13.3	64.8±13.3	64.8±13.3	69.1	13.8±1.7	15.3±1.7	13.0±1.7	17.1±1.7	14.8	**
ICC 6294©	83.0±13.3	69.2±13.3	64.8±13.3	64.8±4.1	69.1	13.8±1.7	15.3±1.7	13.0±1.7	17.1±1.7	14.8	**

Continue Table 4.2

ICCV 07102[©]	83.0±13.3	69.2±13.3	64.8±13.3	64.8±13.3	69.1	13.8±1.7	15.3±1.7	13.0±1.7	17.1+1.7	14.8	**
ICCV 00104[©]	83.0±13.3	69.2±13.3	64.8±13.3	64.8±13.3	69.1	13.8±1.7	15.3±1.7	13.0±1.7	17.1±1.7	14.8	**
ICC 10685	86.0±4.7	74.1±3.6	70.1±5.5	68.1±4.1	74.6	12.0±0.7	13.4±0.6	11.4±0.7	15.0±0.6	12.9	**
ICC 7413	88.5±5.4	71.4±3.6	68.6±5.5	61.3±4.1	69.7	13.6±0.8	14.4±0.6	13.3±0.7	17.0±0.6	14.6	**
ICCV 10	81.1±4.7	69.6±3.6	67.3±6.1	57.4±4.1	68.0	16.2±0.7	17.4±0.6	14.8±0.7	19.0±0.6	16.8	**
ICC 7326	103.4±4.7	88.1±3.6	81.6±5.5	84.3±4.1	82.9	17.9±0.7	17.5±0.6	16.9±0.7	20.1±0.6	18.1	**
ICC 9712	103.5±4.7	83.6±3.6	84.6±5.5	86.7±4.1	83.1	15.0±0.7	15.0±0.6	14.0±0.7	18.6±0.6	15.7	**
ICC 14815	70.6±4.7	51.1±3.6	57.6±5.5	55.2±4.1	60.4	13.2±0.7	15.8±0.6	12.6±0.7	16.4±0.6	14.5	**
ICC 4657	68.8±4.7	62.6±3.6	47.8±5.5	55.2±4.1	60.8	12.8±0.7	14.3±0.6	11.6±0.7	16.7±0.6	13.8	**
ICC 1164	73.1±4.7	58.5±3.6	53.6±5.5	55.1±4.1	60.1	12.3±0.7	13.8±0.6	11.6±0.7	15.9±0.6	13.4	**
ICC 14051	74.6±4.8	46.1±3.6	60.5±6.1	64.0±4.1	62.1	12.5±0.7	13.4±0.6	11.6±0.7	17.0±0.6	13.6	**
ICC 12851	88.4±5.4	69.7±3.6	68.0±6.1	67.4±4.1	73.4	11.9±0.7	13.5±0.6	11.5±0.7	16.0±0.6	13.2	**
ICC 4991	71.0±4.7	67.7±3.6	63.6±5.5	62.3±4.1	67.8	11.8±0.7	13.6±0.6	11.1±0.7	16.1±0.6	13.1	**
ICC 506	76.7±4.7	52.4±3.6	57.4±5.5	69.2±4.1	64.2	13.3±0.7	16.2±0.6	12.6±0.7	17.8±0.6	15.0	**
ICC 9702	107.5±4.7	95.4±3.6	86.4±5.5	77.4±4.1	84.2	14.8±0.7	17.8±0.6	13.5±0.7	18.1±0.6	16.0	**
ICCV 07111	66.5±4.7	49.7±3.6	47.1±5.5	51.0±4.1	56.3	15.8±0.7	15.3±0.6	15.1±0.7	18.2±0.6	16.1	**
ICC 1398	69.5±4.7	50.5±3.6	49.7±5.5	51.7±4.1	57.4	15.3±0.7	15.9±0.6	14.7±0.7	17.6±0.6	15.9	**
ICC 13124	77.6±4.8	65.4±3.6	57.8±6.1	69.6±4.1	67.6	14.2±0.8	16.5±0.6	13.9±0.7	18.4±0.6	15.7	**
ICC 6877	106.8±4.7	95.6±3.6	80.3±5.5	81.7±4.1	83.8	17.6±0.7	20.2±0.6	16.9±0.7	20.5±0.6	18.8	**
ICC 4872	73.5±4.7	65.8±3.6	55.6±5.5	64.3±4.1	65.9	12.9±0.7	15.4±0.6	11.8±0.7	16.0±0.6	14.0	**
ICC 11198	72.8±4.7	61.6±3.6	53.5±5.5	47.6±4.1	58.8	13.0±0.7	14.4±0.6	12.0±0.7	16.9±0.6	14.1	**
ICC 5613	77.8±4.7	70.8±3.6	70.8±5.5	74.2±4.1	73.3	14.4±0.7	16.2±0.6	13.7±0.7	17.6±0.6	15.5	**
ICC 9895	108.5±5.4	95.4±3.6	77.8±6.1	92.3±4.1	85.8	14.1±0.7	15.6±0.6	13.3±0.8	17.7±0.6	15.2	**
ICC 11903	95.6±4.7	86.9±3.6	79.8±5.5	75.7±4.1	84.5	16.6±0.7	16.9±0.6	15.5±0.7	18.8±0.6	16.9	**
ICC 1397	77.9±5.4	69.6±3.6	54.4±6.1	52.7±4.1	63.6	13.7±0.8	14.2±0.6	12.8±0.8	16.7±0.6	14.3	**
ICC 8522	82.9±4.7	63.6±3.6	67.1±5.5	71.6±4.1	70.0	12.5±0.7	15.6±0.6	11.7±0.7	16.2±0.6	14.0	**
ICC 11944	63.0±4.7	49.6±3.6	42.7±5.5	47.0±4.1	50.6	11.5±0.7	13.5±0.6	11.1±0.7	15.0±0.6	12.8	**
ICC 9862	97.8±4.7	95.9±3.6	67.8±6.1	74.0±4.1	78.8	13.7±0.7	15.6±0.6	13.2±0.7	17.3±0.6	14.9	**
ICC 791	63.4±4.7	50.8±3.6	47.2±5.5	66.8±4.1	60.6	11.0±0.7	12.8±0.6	10.3±0.7	14.3±0.6	12.1	**
ICC 9002	70.1±4.7	58.4±3.6	44.1±5.5	57.0±4.1	59.3	12.4±0.7	13.6±0.6	11.7±0.7	16.7±0.6	13.6	**
Mean	83.0	69.2	64.8	64.8	69.3	13.8	15.3	13.0	17.1	14.8	
Minimum	63.0	46.1	42.7	47.0	50.6	11.0	12.8	10.3	14.3	12.1	
Maximum	108.5	100.8	88.0	92.3	85.8	17.9	20.2	16.9	20.5	18.8	

** - significant at 1 %, * - significant at 5 % and NS – non –significant at 5 % level of significant , [©]- Genotypes were analysed using missing block and hence they have the same values for all traits, Pr- Probability value

Plant Height

There were highly significant ($p < 0.0001$) differences among the genotypes and genotype by environment interactions for plant height (Table 4.3). All genotypes recorded taller plant height in Juja compared to Kabete. Genotypes recorded taller plant height during long rains compared to short rains at Juja. While at Kabete some genotypes recorded taller plant height during short rains and vice versa. Some of the tall (ICC 6877, ICC 4182, ICC 7867 and ICC 9702) and short (ICC 11194, ICC 4657, ICC 11198 and ICC 9002) genotypes at Juja also recorded tall and short at Kabete. The ranking of genotypes for plant height varied across environments except ICC 11944 which consistently recorded short plant height across environments. Twenty and seventeen genotypes were taller than the check varieties ICCV 00108 and ICCV 97105 in plant height individually.

Based on overall means, genotypes showed differences for plant height and twelve genotypes were categorized as short (< 40 cm), 44 genotypes as medium (40.1 – 55 cm) and 4 genotypes were tall (> 55 cm). Genotypes ICC 7867 (57.6 cm) and ICC 9712 (56.4 cm) followed by ICC 6877 (51.1 cm), ICC 4182 (55.6 cm) and ICC 9895 (54.3 cm) were the tallest. While genotypes ICC 11944 (31.4 cm) and ICC 4657 (35.3 cm) followed by ICC 11198 (35.5 cm), ICC 9002 (36.6 cm) and ICC 1356 (37.7 cm) were the shortest. The check varieties ICCV 00108 (45.5 cm) and ICCV 97105 (46.6 cm) were classified as medium. Based on environment wise means, the tallest plant height was recorded in long rain season Juja (52.0 cm) followed by short rain season Juja (46.0 cm), short rain season Kabete (41.0 cm) and long rain season Kabete (39.5 cm) with a grand mean of 44.8 cm.

Number of Primary Branches

Genotypes and genotype by environment interactions showed highly significant ($p < 0.0001$) variation for number of primary branches plant $^{-1}$ (Table 4.3). All genotypes recorded the higher number of primary branches plant $^{-1}$ at Juja compared to Kabete All assessed genotypes recorded higher number of primary branches plant $^{-1}$ in long rains compared to short rains at Juja. While at Kabete some genotypes recorded higher number of primary branches plant $^{-1}$ in short rains and vice versa. The ranking of genotypes for number of primary branches plant $^{-1}$ varied across environments.

Fifty one and thirty seven genotypes surpassed the check varieties ICCV 00108 and ICCV 97105 for primary branches plant $^{-1}$.

On the basis of overall means, the evaluated genotypes differed in number of primary branches plant $^{-1}$ and 24 genotypes were classified as low (< 13), 27 genotypes as medium (13.5 – 15.0) and 9 genotypes as high (> 15). The highest number of primary branches plant $^{-1}$ was recorded for genotypes ICC 1715 (17.5) and ICC 12928 (17.4) followed by ICC 5639 (16.8), ICC 5504 (16.6) and ICC 4182 (16.5). While genotypes ICC 1356 (11.4), ICC 1398 (11.6), ICC 13124 (11.6), ICCV 07111 (11.8) and ICC 14051(11.8) recorded the lowest number of primary branches plant $^{-1}$. The check varieties ICCV 00108 (12.3) and ICCV 97105 (13.4) were classified as genotypes with low primary branches plant $^{-1}$. With respect to environment wise means, the highest number of primary branches plant $^{-1}$ was recorded in long rain season Juja (17.4) followed by short rain season Juja (16.4), long rain season Kabete (11.4) and short rain Kabete (10.1) with a grand mean of 13.8.

Table 4.3: Variation among *Desi* Genotypes for Plant Height and Number of Primary Branches Plant $^{-1}$ at Juja and Kabete

	Plant Height in centimeters					Number of Primary Branches Plant $^{-1}$					
Genotypes	Long rain Juja Mean±S.E	Short rain Juja Mean±S.E	Long rain Kabete Mean±S.E	Short rain Kabete Mean±S.E	Overall Mean	Long rain Juja Mean±S.E	Short rain Juja Mean±S.E	Long rain Kabete Mean±S.E	Short rain Kabete Mean±S.E	Overall Mean	Pr.
ICC 9636	53.2±3.0	43.2±2.3	39.3±3.0	41.5±1.8	44.3	20.5±1.7	15.3±1.1	13.4±1.4	11.7±0.6	15.2	**
ICCV 97105 (Check)	56.0±3.0	49.1±2.3	41.6±3.0	39.6±1.8	46.6	18.1±1.7	15.9±1.1	12.1±1.4	7.7±0.6	13.4	**
ICCV 00108 (Check)	52.6±3.0	46.3±2.3	41.7±3.0	41.3±1.8	45.5	15.6±1.7	13.6±1.1	11.6±1.4	8.5±0.6	12.3	**
ICC 6579	48.1±3.0	42.5±2.3	38.0±3.0	40.4±1.8	42.2	16.7±1.7	17.5±1.1	12.4±1.4	11.9±0.6	14.6	**
ICC 5639	50.6±3.0	41.3±2.3	37.8±3.0	39.1±1.8	42.2	18.7±1.7	22.8±1.1	12.5±1.4	13.4±0.6	16.8	**
ICC 1052	61.7±3.0	50.7±2.3	44.5±3.0	45.9±1.8	50.7	18.7±1.7	18.3±1.1	10.6±1.4	9.6±0.6	14.3	**
ICC 15614	49.7±3.0	39.9±2.3	38.2±3.0	35.3±1.8	40.8	18.2±1.7	17.5±1.1	13.8±1.4	7.7±0.6	14.3	**
ICC 3325	48.4±3.0	35.8±2.3	32.8±3.0	35.5±1.8	38.1	19.8±1.7	11.0±1.1	12.7±1.4	9.6±0.6	13.3	**
ICC 16915	59.0±3.0	50.4±2.3	45.8±3.0	43.9±1.8	49.8	18.2±1.7	18.4±1.1	12.1±1.4	9.9±0.6	14.6	**
ICC 4182	63.8±3.0	59.1±2.3	49.5±3.0	49.9±1.8	55.6	17.1±1.7	24.9±1.1	11.9±1.4	12.2±0.6	16.5	**
ICC 7867	65.9±3.0	62.2±2.3	50.5±3.0	51.7±1.8	57.6	16.9±1.7	23.3±1.1	11.6±1.4	9.8±0.6	15.4	**
ICC 1356	45.5±3.0	36.9±2.3	30.8±3.0	37.6±1.8	37.7	15.9±1.7	11.7±1.1	10.2±1.4	8.0±0.6	11.4	**
ICC 1422	51.9±3.0	45.0±2.3	38.6±3.0	39.6±1.8	43.8	19.2±1.7	14.2±1.1	11.6±1.4	8.8±0.6	13.4	**
ICC 4093	53.9±3.0	48.2±2.3	41.2±3.0	41.1±1.8	46.1	18.9±1.7	22.0±1.1	11.7±1.4	10.3±0.6	15.7	**
ICC 16261	54.0±3.0	41.1±2.3	41.3±3.0	39.8±1.8	44.0	18.6±1.7	16.7±1.1	12.3±1.4	10.8±0.6	14.6	**
ICC 1715	50.1±3.0	42.1±2.3	35.8±3.0	38.0±1.8	41.5	23.1+1.7	20.9±1.1	12.7±1.4	13.1±0.6	17.5	**
ICC 8318	48.8±3.0	39.4±2.3	41.3±3.0	39.9±1.8	42.4	17.4±1.7	15.2±1.1	11.9±1.4	10.6±0.6	13.8	**
ICC 2580	56.8±3.0	53.1±2.3	39.8±3.0	42.8±1.8	48.1	18.7±1.7	14.0±1.1	12.1±1.4	8.4±0.6	13.3	**
ICC 16524	47.0±3.0	40.3±2.3	34.7±3.0	34.3±1.8	39.1	17.3±1.7	14.2±1.1	12.3±1.4	8.0±0.6	13.0	**
ICC 4463	57.4±3.0	55.1±2.3	45.6±3.0	46.4±1.8	51.1	14.7±1.7	16.1±1.1	13.6±1.4	13.0±0.6	14.4	**
ICC 1392	51.0±3.0	44.9±2.3	36.2±3.0	37.2±1.8	42.3	17.2±1.7	14.8±1.1	11.0±1.4	7.6±0.6	12.6	**
ICC 5504	57.8±3.0	53.3±2.3	48.8±3.0	43.4±1.8	50.8	19.5±1.7	24.0±1.1	12.4±1.4	10.6±0.6	16.6	**
ICC 9872	61.5±3.0	55.4±2.3	49.7±3.2	43.9±1.8	52.6	16.0±1.7	17.2±1.1	11.0±1.4	7.7±0.6	13.0	**
ICC 2242	54.5±3.0	45.2±2.3	39.1±3.0	40.0±1.8	44.7	19.9±1.7	19.8±1.1	12.7±1.4	10.3±0.6	15.7	**
ICC 1510	48.6±3.0	42.6±2.3	33.9±3.0	37.7±1.8	40.7	16.2±1.7	14.5±1.1	9.5±1.4	9.7±0.6	12.5	**
ICC 12928	52.9±3.0	44.4±2.3	38.0±3.0	41.7±1.8	44.2	22.6±1.7	18.4±1.1	14.1±1.4	14.6±0.6	17.4	**
Annigeri©	52.8±7.0	46.0±6.9	39.5±7.0	41.0±6.9	44.8	17.4±2.6	16.4±2.6	11.4±2.6	10.1±2.5	13.8	**
ICC 8200©	52.8±7.0	46.0±6.9	39.5±7.0	41.0±6.9	44.8	17.4±2.6	16.4±2.6	11.4±1.4	10.1±2.5	13.8	**
ICC 4918©	52.8±7.0	46.0±6.9	39.5±7.0	41.0+6.9	44.8	17.4±2.6	16.4±2.6	11.4±2.6	10.1±2.5	13.8	**

Continue Table 4.3

ICC 6294©	52.8±7.0	46.0±6.9	39.5±7.0	41.0±6.9	44.8	17.4±2.6	16.4±2.6	11.4±2.6	10.1±2.5	13.8	**
ICCV 07102©	52.8±7.0	46.0±6.9	39.5±7.0	41.0±6.9	44.8	17.4±2.6	16.4±1.1	11.4±2.6	10.1±2.5	13.8	**
ICCV 00104©	52.8±7.0	46.0±6.9	39.5±7.0	41.0±6.9	44.8	17.4±2.6	16.4±2.6	11.4±2.6	10.1±2.5	13.8	**
ICC 10685	56.5±3.0	52.1±2.3	43.8±3.0	44.6±1.8	49.2	15.7±1.7	13.9±1.1	10.2±1.4	7.9±0.6	11.9	**
ICC 7413	50.4±3.2	43.5±2.3	39.3±3.0	39.7±1.8	43.2	17.4±1.8	17.0±1.1	12.5±1.4	9.8±0.6	14.2	**
ICCV 10	49.7±3.0	39.4±2.3	35.±3.0	36.4±1.8	40.1	16.4±1.7	15.1±1.1	9.9±1.4	11.1±0.6	13.1	**
ICC 7326	61.0±3.0	53.4±2.3	48.1±3.0	46.2±1.8	52.2	17.9±1.7	16.7±1.1	12.3±1.4	10.5±0.6	14.4	**
ICC 9712	68.8±3.0	56.1±2.3	52.0±3.0	48.6±1.8	56.4	18.4±1.7	15.3±1.1	11.4±1.4	10.2±0.6	13.8	**
ICC 14815	46.2±3.0	40.5±2.3	36.4±3.0	37.4±1.8	40.1	18.0±1.7	11.6±1.1	14.8±1.4	8.4±0.6	13.2	**
ICC 4657	41.7±3.0	38.4±2.3	27.9±3.0	33.3±1.8	35.3	18.2±1.8	16.1±1.1	9.3±1.4	11.1±0.6	13.7	**
ICC 1164	46.7±3.0	39.6±2.3	34.4±3.0	37.0±1.8	39.4	16.1±1.7	16.2±1.1	11.5±1.4	8.5±0.6	13.1	**
ICC 14051	47.7±3.0	40.2±2.3	33.1±3.0	37.9±1.8	39.7	15.4±1.7	11.6±1.1	10.0±1.4	10.1±0.6	11.8	**
ICC 12851	50.9±3.0	44.2±2.3	36.9±3.0	41.0±1.8	43.3	14.8±1.7	14.6±1.1	9.1±1.4	8.8±0.6	11.8	**
ICC 4991	45.0±3.0	41.6±2.3	34.8±3.0	37.1±1.8	39.6	13.6±1.7	16.0±1.1	12.0±1.4	9.5±0.6	12.8	**
ICC 506	49.5±3.0	39.4±2.3	36.1±3.0	38.3±1.8	40.8	17.6±1.7	17.0±1.1	10.2±1.4	11.5±0.6	14.1	**
ICC 9702	62.8±3.0	54.4±2.3	51.6±3.0	48.1±1.8	54.2	16.3±1.7	13.7±1.1	10.2±1.4	10.3±0.6	12.6	**
ICCV 07111	56.9±3.0	49.4±2.3	41.3±3.0	46.0±1.8	48.4	15.4±1.7	14.7±1.1	7.9±1.4	9.2±0.6	11.8	**
ICC 1398	46.9±3.0	41.3±2.3	33.6±3.0	36.6±1.8	39.6	15.4±1.7	12.1±1.1	9.5±1.4	9.5±0.6	11.6	**
ICC 13124	51.4±3.0	48.6±2.3	39.8±3.0	43.3±1.8	45.8	14.5±1.7	12.7±1.1	10.5±1.4	8.7±0.6	11.6	**
ICC 6877	65.1±3.0	62.7±2.3	50.7±3.0	46.1±1.8	56.1	17.0±1.8	14.8±1.1	11.9±1.4	10.7±0.6	13.6	**
ICC 4872	51.0±3.0	48.6±2.3	37.0±3.0	41.0±1.8	44.4	17.2±1.7	20.7±1.1	10.1±1.4	10.0±0.6	14.5	**
ICC 11198	42.8±3.0	35.3±2.3	30.5±3.0	33.4±1.8	35.5	16.2±1.7	14.1±1.1	11.0±1.4	8.1±0.6	12.4	**
ICC 5613	48.9±3.0	43.9±2.3	40.0±3.0	42.8±1.8	43.9	14.0±1.7	13.5±1.1	10.3±1.4	10.1±0.6	12.0	**
ICC 9895	61.8±3.3	59.9±2.3	48.2±3.2	47.2±1.8	54.3	17.3±1.8	18.9±1.1	9.7±1.6	10.1±0.6	14.0	**
ICC 11903	61.7±3.0	52.5±2.3	46.9±3.0	50.7±1.8	53.0	18.5±1.7	14.9±1.1	12.6±1.4	11.4±0.6	14.3	**
ICC 1397	49.2±3.3	41.2±2.3	35.5±3.2	37.9±1.8	41.0	17.3±1.8	17.4±1.1	11.7±1.4	8.7±0.6	13.8	**
ICC 8522	51.4±3.0	44.6±2.3	39.5±3.0	43.2±1.8	44.7	18.7±1.8	14.2±1.1	9.6±1.4	11.3±0.6	13.5	**
ICC 11944	38.2±3.0	31.8±2.3	24.4±3.0	31.0±1.8	31.4	16.9±1.7	17.3±1.1	12.3±1.4	10.5±0.6	14.3	**
ICC 9862	60.4±3.0	56.3±2.3	43.4±3.2	46.4±1.8	51.6	16.2±1.7	21.1±1.1	8.6±1.6	9.8±0.6	13.9	**
ICC 791	46.0±3.0	38.7±2.3	30.4±3.0	40.3±1.8	38.9	15.6±1.7	15.7±1.1	10.1±1.4	14.0±0.6	13.9	**
ICC 9002	44.1±3.0	38.8±2.3	28.1±3.0	35.4±1.8	36.6	21.5±1.7	14.5±1.1	11.4±1.4	10.8±0.6	14.5	**
Mean	52.8	46.0	39.5	41.0	44.8	17.4	16.4	11.4	10.1	13.8	
Minimum	38.2	31.8	24.4	31.0	31.4	13.6	11.0	7.9	7.6	11.4	
Maximum	68.8	62.7	52.0	51.7	57.6	23.1	24.9	14.8	14.7	17.5	

Number of Secondary Branches

There were highly significant ($p < 0.0001$) differences among genotypes and genotypes by environment interactions for number of secondary branches plant $^{-1}$ (Table 4.4). All the genotypes recorded higher number of secondary branches plant $^{-1}$ at Juja compared to Kabete. The ranking of genotypes for number of secondary branches plant $^{-1}$ varied across environments. Fifty seven and forty three genotypes exceeded the check varieties ICCV 00108 and ICCV 97105 for number of secondary branches plant $^{-1}$ respectively.

Based on overall means, the evaluated genotypes indicated a wide range of variation for number of secondary branches plant $^{-1}$. Sixteen genotypes had low (< 27.5), 12 genotypes were moderate (27.5 – 30.0) and 32 genotypes had high (> 30). The highest number of secondary branches plant $^{-1}$ was recorded in genotypes ICC 7867 (38.9) and ICC 5639 (38.0) followed by ICC 1052 (37.9), ICC 2242 (37.3) and ICC 4182 (36.4). Genotypes ICCV 07111 (22.5), ICC 1398 (24.0), ICCV 00108 (24.0), ICC 12851 (24.5) and ICC 13124 (24.8) recorded the lowest number of secondary branches plant $^{-1}$. The check varieties ICCV 00108 (24.0) and ICCV 97105 (27.4) were classified as genotypes with low secondary branches plant $^{-1}$. Based on the environment wise means, the highest number of secondary branches plant $^{-1}$ was recorded during short rain season at Juja (44.6) followed by long rain season Juja (40.1), short rain season Kabete (20.6) and long rain season Kabete (15.4) with a grand mean of 30.2.

Days to 75 % Maturity

Genotypes and genotype by environment interactions showed highly significant ($p < 0.0001$) differences for days to 75 % physiological maturity (Table 4.4). All the genotypes took longer time to mature in the long rains compared to short rains at both sites. In addition, all studied genotypes took longer time to mature at Kabete compared to Juja in both seasons. The ranking of genotypes for days to maturity differed across environments. Forty and twenty 22 genotypes matured earlier than the check varieties ICCV 00108 and ICCV 97105.

On the basis of overall means, the results indicated a wide range of variation among genotypes in maturity. Fifteen genotypes were classified as early (< 115 days), 32 genotypes as moderate (115.0 – 120.0 days) and 14 genotypes as late (> 120 days).

Genotypes ICC 2580 (111.0 days) and ICC 15614 (111.0 days) followed by ICC 14815 (112.0 days), ICC 3325 (112.0 days) and ICC 1397 (112.0 days) were the earliest in maturity. While genotypes ICC 5639 (127.0 days) followed by ICC 4463 (124.0days), ICC 7867 (124.0 days), ICC 4182 (124.0 days) and ICC 1052 (124.0days) were the latest. The check varieties ICCV 00108 (118.0 days) and ICCV 97105 (116.0 days) were categorized as moderate. Based on environment wise means, the earliest maturity was recorded in short rain season at Juja (98.0 days) followed by short rain season at Kabete (105.0 days), long rain season at Juja (125.0 days) and long rain season Kabete (142.0 days) with a grand mean of 117.0 days.

Table 4.4: Variation among *Desi* Genotypes for Secondary Branches Plant $^{-1}$ and Days to Maturity at Juja and Kabete

	Number of Secondary Branches Plant $^{-1}$					Days to 75 % Maturity					
Genotypes	Long rain Juja Mean±S.E	Short rain Juja Mean±S.E	Long rain Kabete Mean±S.E	Short rain Kabete Mean±S.E	Overall Mean	Long rain Juja Mean±S.E	Short rain Juja Mean±S.E	Long rain Kabete Mean±S.E	Short rain Kabete Mean±S.E	Overall Mean	Pr.
ICC 9636	41.8±4.9	39.5±4.2	21.1±3.2	38.3±1.0	35.1	125.0±2.6	98.9±1.6	144.5±2.4	101.9±1.6	117.6	**
ICCV 97105 (Check)	36.8±4.9	40.7±4.2	14.8±3.2	17.2±1.0	27.4	122.1±2.6	97.9±1.6	144.4±2.4	98.5±1.6	115.7	**
ICCV 00108 (Check)	33.6±4.9	33.3±4.2	13.6±3.2	15.6±1.0	24.0	120.4±2.6	94.3±1.6	144.3±2.4	113.4±1.6	118.1	**
ICC 6579	40.0±4.9	42.6±4.2	17.1±3.2	15.0±1.0	28.6	122.8±2.6	102.9±1.6	135.6±2.4	97.5±1.6	114.7	**
ICC 5639	48.6±5.5	54.4±4.2	21.4±3.2	27.5±1.0	38.0	127.9±2.6	107.9±1.6	147.1±2.4	123.0±1.6	126.5	**
ICC 1052	54.3±4.9	59.8±4.2	14.5±3.2	23.0±1.0	37.9	124.9±2.6	105.3±1.6	141.6±2.4	123.2±1.6	123.8	**
ICC 15614	46.0±4.9	55.6±4.2	23.9±3.2	14.5±1.0	35.0	121.7±2.6	89.4±1.6	147.1±2.4	86.8±1.6	111.3	**
ICC 3325	41.0±4.9	25.2±4.2	22.1±3.2	18.2±1.0	26.7	121.5±2.6	96.3±1.6	144.6±2.4	85.9±1.6	112.1	**
ICC 16915	38.2±4.9	48.2±4.2	13.4±3.2	22.1±1.0	30.5	121±2.6	92.1±1.6	144.4±2.4	105.3±1.6	115.7	**
ICC 4182	33.8±5.5	74.3±4.2	13.7±3.2	23.8±1.0	36.4	129.6±2.6	103.1±1.6	141.1±2.4	123.2±1.6	124.3	**
ICC 7867	45.4±4.9	67.7±4.2	13.3±3.2	29.2±1.0	38.9	125.5±2.6	107.2±1.6	141.1±2.4	123.9±1.6	124.4	**
ICC 1356	37.6±4.9	36.1±4.2	15.4±3.2	14.7±1.0	25.9	121.9±2.6	96.3±1.6	138.3±2.4	98.1±1.6	113.7	**
ICC 1422	44.7±4.9	43.9±4.2	18.5±3.2	16.1±1.0	30.8	125.6±2.6	92.6±1.6	143.3±2.4	89.4±1.6	112.7	**
ICC 4093	44.8±4.9	42.6±4.2	17.2±3.2	25.4±1.0	32.5	121.1±2.6	101.2±1.6	143.9±2.4	117.6±1.6	120.9	**
ICC 16261	46.5±4.9	53.5±4.2	18.5±3.2	20.0±1.0	34.7	128.1±2.6	97.3±1.6	145.8±2.4	94.8±1.6	116.5	**
ICC 1715	41.9±4.9	59.8±4.2	19.4±3.2	17.5±1.0	34.7	120.4±2.6	100.1±1.6	141.0±2.4	99.7±1.6	115.3	**
ICC 8318	40.3±4.9	46.4±4.2	16.4±3.2	19.5±1.0	30.6	124.0±2.6	91.4±1.6	141.6±2.4	105.3±1.6	115.6	**
ICC 2580	45.2±4.9	38.3±4.2	15.7±3.2	15.6±1.0	28.7	119.2±2.6	91.6±1.6	138.4±2.4	95.2±1.6	111.1	**
ICC 16524	36.8±4.9	40.0±4.2	15.2±3.2	18.5±1.0	27.6	127.9±2.6	94.6±1.6	146.4±2.4	98.8±1.6	116.9	**
ICC 4463	27.4±5.5	46.9±4.2	17.9±3.2	24.7±1.0	29.2	132.1±2.6	106.9±1.6	138.0±2.4	120.8±1.6	124.4	**
ICC 1392	53.0±4.9	37.6±4.2	15.4±3.2	17.4±1.0	30.9	124.6±2.6	90.8±1.6	140.6±2.4	99.3±1.6	113.8	**
ICC 5504	46.6±4.9	57.1±4.2	16.0±3.2	23.5±1.0	35.8	128.0±2.6	97.7±1.6	141.4±2.4	103.2±1.6	117.6	**
ICC 9872	38.0±4.9	45.2±4.2	13.2±3.2	11.7±1.0	27.0	126.6±2.6	97.8±1.6	142.3±2.4	118.8±1.6	121.4	**
ICC 2242	46.8±4.9	57.1±4.2	19.8±3.2	25.5±1.0	37.3	124.4±2.6	103.4±1.6	143.4±2.4	112.9±1.6	121.0	**
ICC 1510	36.9±4.9	41.5±4.2	11.5±3.2	20.9±1.0	27.7	125.9±2.6	99.4±1.6	144.0±2.4	121.0±1.6	122.6	**
ICC 12928	45.8±4.9	43.0±4.2	24.6±3.2	22.7±1.0	34.0	123.5±2.6	104.7±1.6	148.3±2.4	116.4±1.6	123.2	**
Annigeri©	40.1±7.9	44.6±7.9	15.4±7.9	20.6±7.9	30.2	124.6±6.6	97.9±6.6	141.8±6.6	105.3±6.6	117.4	**
ICC 8200©	40.1±7.9	44.6±7.9	15.4±7.9	20.6±7.9	30.2	124.6±6.6	97.9±6.6	141.8+6.6	105.3±6.6	117.4	**
ICC 4918©	40.1±7.9	44.6±7.9	15.4±7.9	20.6±7.9	30.2	124.6±6.6	97.9±6.6	141.8+6.6	105.3±6.6	117.4	**

Continue Table 4.4

ICC 6294©	40.1±7.9	44.6±7.9	15.4±7.9	20.6±7.9	30.2	124.6±6.6	97.9±6.6	141.8±6.6	105.3±6.6	117.4	**
ICCV 07102©	40.1±7.9	44.6±7.9	15.4±7.9	20.6±7.9	30.2	124.6±6.6	97.9±6.6	141.8±6.6	105.3±6.6	117.4	**
ICCV 00104©	40.1±7.9	44.6±7.9	15.4±7.9	20.6±7.9	30.2	124.6±6.6	97.9±6.6	141.8±6.6	105.3±6.6	117.4	**
ICC 10685	34.1±4.9	42.8±4.2	12.0±3.2	13.8±1.0	25.7	120.4±2.6	97.9±1.6	136.8±2.4	105.9±1.6	115.2	**
ICC 7413	48.8±6.4	54.2±4.2	18.2±3.2	22.1±1.0	35.9	125.8±3.1	99.8±1.6	139.6±2.4	96.6±1.6	115.4	**
ICCV 10	41.5±4.9	42.2±4.2	11.0±3.2	15.8±1.0	27.6	126.3±2.6	88.6±1.6	143.1±2.4	96.8±1.6	113.7	**
ICC 7326	46.3±4.9	45.6±4.2	17.0±3.2	27.9±1.0	34.2	125.8±2.6	100.0±1.6	140.0±2.4	118.2±1.6	121.0	**
ICC 9712	44.9±4.9	34.7±4.2	17.7±3.2	12.8±1.0	27.5	123.5±2.6	96.5±1.6	139.9±2.4	119.7±1.6	119.9	**
ICC 14815	38.1±4.9	35.4±4.2	21.9±3.2	20.8±1.0	29.0	122.5±2.6	92.5±1.6	142.4±2.4	88.7±1.6	111.5	**
ICC 4657	45.5±4.9	43.4±4.2	10.5±3.2	23.1±1.0	30.6	123.7±2.6	98.6±1.6	144.4±2.4	97.8±1.6	116.1	**
ICC 1164	34.6±4.9	42.6±4.2	15.8±3.2	20.7±1.0	28.4	124.9±2.6	99.0±1.6	141.9±2.4	114.1±1.6	120.0	**
ICC 14051	35.4±4.9	32.7±4.2	14.8±3.2	17.4±1.0	25.1	124.0±2.6	93.3±1.6	144.3±2.4	100.9±1.6	115.6	**
ICC 12851	32.2±4.9	39.8±4.2	11.9±3.2	13.9±1.0	24.5	126.8±2.6	100.3±1.6	145.0±2.4	107.9±1.6	120.0	**
ICC 4991	23.4±5.5	45.7±4.2	13.8±3.2	20.3±1.0	25.8	126.1±2.6	95.8±1.6	139.3±2.4	100.6±1.6	115.5	**
ICC 506	41.3±4.9	41.1±4.2	11.3±3.2	15.5±1.0	27.3	126.2±2.6	98.0±1.6	136.8±2.4	115.0±1.6	119.0	**
ICC 9702	47.8±4.9	32.8±4.2	12.5±3.2	16.7±1.0	27.4	124.6±2.6	102.6±1.6	136.9±2.4	102.2±1.6	116.6	**
ICCV 07111	31.9±4.9	37.4±4.2	8.8±3.2	12.0±1.0	22.5	120.8±2.6	94.8±1.6	139.7±2.4	96.8±1.6	113.0	**
ICC 1398	32.9±4.9	34.6±4.2	10.8±3.2	17.7±1.0	24.0	123.8±2.6	92.3±1.6	146.7±2.4	92.5±1.6	113.8	**
ICC 13124	27.7±4.9	35.5±4.2	16.1±3.2	19.9±1.0	24.8	125.1±2.6	92.7±1.6	140.2±2.4	105.3±1.6	115.8	**
ICC 6877	46.6±4.9	45.9±4.2	15.2±3.2	20.2±1.0	32.0	124.4±2.6	102.1±1.6	140.3±2.4	117.9±1.6	121.2	**
ICC 4872	37.7±4.9	51.3±4.2	11.6±3.2	17.3±1.0	29.5	123.9±2.6	96.1±1.6	136.7±2.4	102.5±1.6	114.8	**
ICC 11198	35.1±4.9	35.1±4.2	12.3±3.2	19.7±1.0	25.5	122.7±2.6	97.6±1.6	138.6±2.4	94.3±1.6	113.3	**
ICC 5613	29.1±4.9	37.8±4.2	11.7±3.2	21.9±1.0	25.1	128.1±2.6	95.8±1.6	139.6±2.4	98.8±1.6	115.5	**
ICC 9895	47.3±5.5	54.2±4.2	10.3±3.8	18.1±1.0	32.5	125.1±3.1	99.9±1.6	139.5±2.9	105.0±1.6	117.4	**
ICC 11903	50.7±5.5	36.0±4.2	23.7±3.2	23.1±1.0	33.4	126.6±2.6	100.3±1.6	141.1±2.4	116.9±1.6	121.2	**
ICC 1397	43.8±5.5	46.3±4.2	19.3±3.8	17.7±1.0	31.8	120.3±3.1	99.7±1.6	139.8±2.9	89.7±1.6	112.4	**
ICC 8522	29.7±4.9	36.8±4.2	11.2±3.2	25.5±1.0	25.8	128.7±2.6	93.3±1.6	138.8±2.4	105.6±1.6	116.6	**
ICC 11944	38.9±4.9	41.3±4.2	14.7±3.2	32.5±1.0	31.8	126.3±2.6	99.2±1.6	148.1±2.4	94.1±1.6	116.9	**
ICC 9862	40.9±4.9	65.8±4.2	9.1±3.8	26.6±1.0	35.6	125.4±2.6	102.7±1.6	139.3±2.9	111.9±1.6	119.8	**
ICC 791	30.9±4.9	49.5±4.2	12.5±3.2	34.3±1.0	31.8	130.1±2.6	100.7±1.6	146.6±2.4	115.5±1.6	123.2	**
ICC 9002	34.6±5.5	38.2±4.2	12.8±3.2	27.7±1.0	28.3	122.8±2.6	96.4±1.6	138.7±2.4	102.5±1.6	115.1	**
Mean	40.1	44.6	15.4	20.6	30.2	124.6	97.9	141.8	105.3	117.4	
Minimum	23.4	25.2	8.8	11.7	22.5	119.2	88.6	135.6	85.9	111.1	
Maximum	54.3	74.3	24.6	38.3	38.9	132.1	107.9	148.3	123.9	126.5	

Pod Filling Period

Genotype and genotype by environment interactions showed highly significant ($p < 0.0001$) differences for pod filling period (Table 4.5). All genotypes took a shorter pod filling period in the short rains as compared to long rains at Juja and Kabete. The assessed genotypes took longer pod filling period at Kabete compared to Juja in both seasons. The earliest (ICC 1397, ICC 11944, ICC 791 and ICC 1397) genotypes for pod filling period at Juja also recorded the earliest at Kabete. While the latest genotypes for pod filling period at Kabete were not necessarily the latest at Juja. The ranking of genotypes for pod filling period varied across environments. This indicated no genotypes were performed better across environment rather they responded differently for pod filling period. Forty two and thirty three genotypes were earlier than the check varieties ICCV 00108 and ICCV 97105 for pod filling period respectively.

Based on overall means, the genotypes varied with respect to pod filling period. Eleven genotypes were classified as early (< 55.0 days), 34 genotypes as moderate (55 – 65.0 days) and 15 genotypes as late (> 65.0 days). Genotypes ICC 1397 (48.0 days) and ICC 11944 (49.0 days) followed by ICC 11198 (50.0 days), ICC 791 (52.0 days) and ICC 12928 (53.0 days) were the earliest in pod filling period. While genotypes ICC 506 (73.0 days) followed by ICC 4182 (71.0 days), ICC 8318 (70.0 days), ICC 1052 (69.0 days) and ICC 16915 (69.0 days) were the latest. The check varieties ICCV 00108 (65.0 days) and ICCV 97105 (63.0 days) were classified as moderate. With respect to environment wise means, the earliest pod filling period was recorded in the short rain season Juja (47.0 days) followed by short rain season Kabete (57.0 days), long rain season Juja (62.0 days) and long rain season Kabete (80.0 days) with a grand mean of 62.0 days.

4.1.2. Yield and Yield Related Traits Evaluation

Number of Pods Plant $^{-1}$

There were highly significant ($p < 0.0001$) differences among evaluated genotypes and genotype by environment interactions for number of pods plant $^{--1}$ (Table 4.5). Majority of the evaluated genotypes recorded higher number of pods plant $^{-1}$ during long rains compared to short rain at both sites. Similarly the evaluated genotypes recorded higher mean number of pods plant $^{-1}$ in the long rain season at Juja as compared to long rain season at Kabete. The ranking of genotypes for number of pods plant $^{-1}$ differed across environments (explain their ranking). Fifty four and forty genotypes exceeded the check varieties ICCV 00108 and ICCV 97105 for number of pods plant $^{-1}$ respectively.

On the basis of overall means, the results showed a wide range of differences among genotypes in number of pods plant $^{-1}$. Sixteen genotypes were classified as low (< 120), 26 genotypes as moderate (120 – 150) and 18 genotypes as high (> 150). The highest number of pods plant $^{-1}$ was recorded for genotypes ICC 4182 (244.1) followed by ICC 7867 (225.6), ICC 7326 (190.0), ICC 9636 (184.6) and ICC 9872 (184.1). Genotypes ICC 13124 (101.1) and ICC 9002 (102.5) followed by ICC 11198 (104.4) and ICC 2580 (106.8) recorded the lowest number of pods plant $^{-1}$. The check varieties ICCV 00108 (101.1) and ICCV 97105 (128.1) were categorized as low and moderate respectively. Based on environment-wise means, the highest number of pods plant $^{-1}$ was recorded in long rain season Juja (210.0) followed by short rain season Juja (125.3), long rain season Kabete (121.3) and short rain season Kabete (110.9.) in descending order with a grand mean of 141.9.

Table 4.5: Performance of *Desi* Genotypes for Pod Filling Period and Number of Pods Plant $^{-1}$ at Juja and Kabete

	Pod Filling Period					Number of Pods Plant $^{-1}$					
Genotypes	Long rain Juja Mean±S.E	Short rain Juja Mean±S.E	Long rain Kabete Mean±S.E	Short rain Kabete Mean±S.E	Overall Mean	Long rain Juja Mean±S.E	Short rain Juja Mean±S.E	Long rain Kabete Mean±S.E	Short rain Kabete Mean±S.E	Overall Mean	Pr.
ICC 9636	60.1±3.5	45.2±1.8	65.3±3.5	46.9±1.6	54.4	271.5±31.4	173.2±3.4	168.3±21.5	125.4±4.0	184.6	**
ICCV 97105 (Check)	66.1±3.5	48.9±1.8	84.4±3.5	51.3±1.6	62.7	173.6±31.4	131.2±3.4	118.4±21.5	89.0±4.0	128.1	**
ICCV 00108 (Check)	61.2±3.5	45.2±1.8	91.4±3.5	63.8±1.6	65.4	175.8±31.4	70.6±3.4	114.2±21.5	87.1±4.0	111.9	**
ICC 6579	63.8±3.5	49.8±1.8	81.5±3.5	47.8±1.6	60.7	206.3±31.4	96.8±3.4	150.0±21.5	150.4±4.0	150.9	**
ICC 5639	61.9±3.5	49.3+1.8	77.5±3.5	70.1±1.6	64.7	246.3±34.9	137.1±3.4	136.5±21.5	216.3±4.0	184.0	**
ICC 1052	59.5±3.5	58.3±1.8	84.7±3.5	72.1±1.6	68.6	194.9±31.4	196.3±3.4	104.5±21.5	132.1±4.0	157.0	**
ICC 15614	70.6±3.5	40.4±1.8	93.1±3.5	44.3±1.6	62.1	189.5±31.4	139.0±3.4	167.3±21.5	76.8±4.0	143.1	**
ICC 3325	68.3±3.5	49.2±1.8	86.4±3.5	41.1±1.6	61.3	199.3±31.4	82.2±3.4	190.5±21.5	136.4±4.0	152.1	**
ICC 16915	69.8±3.5	53.2±1.8	89.4±3.5	62.0±1.6	68.6	205.5±31.4	157.0±3.4	122.5±21.5	105.1±4.0	147.5	**
ICC 4182	65.4±3.5	58.4±1.8	86.0±3.5	75.1±1.6	71.2	302.2±34.9	346.4±3.4	145.0±21.5	182.7±4.0	244.1	**
ICC 7867	55.6±3.5	51.9±1.8	79.4±3.5	73.0±1.6	65.0	299.0±31.4	272.9±3.4	135.0±21.5	195.5±4.0	225.6	**
ICC 1356	73.5±3.5	50.6±1.8	87.6±3.5	54.3±1.6	66.5	219.2±31.4	92.4±3.4	105.2±21.5	83.7±4.0	125.1	**
ICC 1422	74.0±3.5	49.0±1.8	88.4±4.1	44.0±1.6	63.9	238.4±31.4	71.1±3.4	131.5±21.5	76.9±4.0	129.5	**
ICC 4093	59.9±3.5	52.9±1.8	89.3±3.5	68.6±1.6	67.7	216.9±31.4	147.6±3.4	118.3±21.5	111.1±4.0	148.5	**
ICC 16261	58.2±3.5	41.5±1.8	78.1±3.5	47.6±1.6	56.3	202.3±31.4	131.0±3.4	141.1±21.5	97.7±4.0	143.0	**
ICC 1715	56.1±3.5	44.0±1.8	77.3±3.5	49.2±1.6	56.7	207.1±31.4	150.8±3.4	103.4±21.5	92.3±4.0	138.4	**
ICC 8318	72.6±3.5	47.0±1.8	97.3±3.5	63.0±1.6	70.0	261.0±34.9	150.5±3.4	160.8±21.5	117.1±4.0	172.3	**
ICC 2580	63.7±3.5	47.0±1.8	86.2±3.5	51.0±1.6	62.0	167.6±34.9	78.4±3.4	85.9±25.2	95.3±4.0	106.8	**
ICC 16524	75.5±3.5	49.3±1.8	82.9±3.5	54.2±1.6	65.5	178.7±31.4	91.3±3.4	128.0±21.5	85.0±4.0	120.7	**
ICC 4463	60.0±3.5	52.2±1.8	80.1±3.5	71.7±1.6	66.0	170.2±34.9	152.6±3.4	121.7±21.5	182.1±4.0	156.6	**
ICC 1392	65.0±3.5	48.0±1.8	83.0±3.5	52.6±1.6	62.1	193.9±31.4	81.9±3.4	119.7±21.5	72.7±4.0	117.1	**
ICC 5504	58.9±3.5	40.3±1.8	83.2±3.5	55.3±1.6	59.4	276.9±31.4	118.2±3.4	144.2±21.5	70.2±4.0	152.4	**
ICC 9872	63.0±3.5	54.8±1.8	78.3±3.5	71.8±1.6	67.0	230.4±31.4	277.0±3.4	161.6±21.5	67.3±4.0	184.1	**
ICC 2242	52.4±3.5	43.6±1.8	60.0±3.5	62.2±1.6	54.6	161.7±34.9	63.4±3.4	148.4±21.5	74.3±4.0	112.0	**
ICC 1510	58.9±3.5	40.3±1.8	70.8±3.5	68.1±1.6	59.5	176.9±31.4	64.2±3.4	112.3±21.5	121.7±4.0	118.8	**
ICC 12928	50.6±3.5	44.2±1.8	60.8±3.5	54.2±1.6	52.4	218.8±31.4	49.0±3.4	150.5±21.5	101.6±4.0	130.0	**
Annigeri©	62.2±9.0	47.2±9.0	80.3±9.0	56.9±9.0	61.7	210.0±49.5	125.3±49.1	121.3±49.2	110.9±49.1	141.9	**
ICC 8200©	62.2±9.0	47.2±9.0	80.3±9.0	56.9±9.0	61.7	210.0±49.5	125.3±49.1	121.3±49.2	110.9±49.1	141.9	**
ICC 4918©	62.2±9.0	47.2±9.0	80.3±9.0	56.9±9.0	61.7	210.0±49.5	125.3±49.1	121.3±49.2	110.9±49.1	141.9	**
ICC 6294©	62.2±9.0	47.2±9.0	80.3±9.0	56.9±9.0	61.7	210.0±49.5	125.3±49.1	121.3±49.2	110.9±49.1	141.9	**

Continue Table 4.5

ICCV 07102©	62.2±9.0	47.2±9.0	80.3±9.0	56.9±9.0	61.7	210.0±49.5	125.3±49.1	121.3±49.2	110.9±49.1	141.9	**
ICCV 00104©	62.2±9.0	47.2±9.0	80.3±9.0	56.9±9.0	61.7	210.0±49.5	125.3±3.4	121.3±49.2	110.9±49.1	141.9	**
ICC 10685	62.3±3.5	50.0±1.8	84.2±3.5	65.1±1.6	65.4	185.9±31.4	115.8±3.4	106.2±21.5	106.6±4.0	128.6	**
ICC 7413	67.1±4.1	50.0±1.8	91.4±3.5	52.7±1.6	65.3	269.2±34.9	196.9±3.4	157.7±21.5	99.5±4.0	180.8	**
ICCV 10	67.4±3.5	53.5+1.8	89.1±3.5	54.3±1.6	66.1	321.4±34.9	143.4±3.4	112.8±21.5	146.3±4.0	181.0	**
ICC 7326	58.4±3.5	41.4±1.8	81.2±3.5	67.5±1.6	62.1	317.4±31.4	66.2±3.4	129.5±21.5	247.0±4.0	190.0	**
ICC 9712	59.3±3.5	39.2±1.8	81.8±3.5	70.7±1.6	62.7	216.3±31.4	84.7±3.4	126.0±21.5	94.0±4.0	130.2	**
ICC 14815	59.6±3.5	38.6±1.8	83.0±3.5	39.0±1.6	55.0	159.8±34.9	76.1±3.4	129.9±21.5	85.7±4.0	112.9	**
ICC 4657	53.2±3.5	45.2±1.8	72.0±3.5	46.9±1.6	54.3	199.5±34.9	180.0±3.4	90.6±21.5	141.7±4.0	152.9	**
ICC 1164	61.7±3.5	43.3±1.8	80.2±3.5	66.6±1.6	62.9	184.0±31.4	71.9±3.4	113.8±21.5	106.4±4.0	119.0	**
ICC 14051	73.5±3.5	54.4±1.8	86.5±3.5	52.4±1.6	66.7	193.3±31.4	104.5±3.4	95.4±21.5	87.7±4.0	120.2	**
ICC 12851	69.1±3.5	54.4±1.8	87.4±3.5	57.2±1.6	67.0	184.2±31.4	100.7±3.4	101.6±21.5	67.4±4.0	113.4	**
ICC 4991	70.0±3.5	41.4±1.8	80.1±3.5	57.3±1.6	62.2	157.5±31.4	141.7±3.4	121.1±21.5	119.1±4.0	134.9	**
ICC 506	73.8±3.5	59.9±1.8	89.4±3.5	68.8±1.6	72.9	157.1±34.9	162.3±3.4	101.1±21.5	97.1±4.0	129.4	**
ICC 9702	52.4±3.5	43.0±1.8	81.2±4.1	48.3±1.6	56.2	235.9±31.4	108.5±3.4	128.0±21.5	89.7±4.0	140.5	**
ICCV 07111	54.4±3.5	54.3±1.8	84.6±3.5	55.4±1.6	62.2	183.8±31.4	133.3±3.4	65.7±21.5	82.0±4.0	116.2	**
ICC 1398	65.2±3.5	57.3±1.8	97.3±3.5	49.9±1.6	67.4	159.7±31.4	120.7±3.4	84.7±21.5	102.7±4.0	116.9	**
ICC 13124	64.7±3.5	46.5±1.8	88.6±3.5	55.2±1.6	63.7	151.3±31.4	86.0±3.4	91.4±21.5	75.6±4.0	101.1	**
ICC 6877	54.1±3.5	47.1±1.8	62.8±4.1	58.1±1.6	55.5	290.6±31.4	86.3±3.4	139.1±21.5	136.2±4.0	163.0	**
ICC 4872	69.1±3.5	59.2±1.8	84.8±3.5	57.2±1.6	67.6	201.2±34.9	167.7±3.4	110.7±21.5	92.6±4.0	143.1	**
ICC 11198	54.5±3.5	40.6±1.8	60.8±3.5	44.3±1.6	50.0	159.5±31.4	95.3±3.4	98.0±21.5	64.7±4.0	104.4	**
ICC 5613	68.1±3.5	45.2+1.8	85.9±3.5	55.1±1.6	63.6	169.5±31.4	102.8±3.4	107.2±21.5	86.2±4.0	116.4	**
ICC 9895	57.1±4.1	44.8±1.8	85.3±4.1	56.0±1.6	60.8	243.0±34.9	200.4±3.4	109.2±25.2	69.6±4.0	155.5	**
ICC 11903	50.0±3.5	38.3±1.8	65.6±3.5	63.5±1.6	54.3	202.4±31.4	53.5±3.4	137.9±21.5	58.9±4.0	113.2	**
ICC 1397	49.9±4.1	40.6±1.8	58.6±4.1	41.7±1.6	47.7	245.9±34.9	53.4±3.4	102.9±21.5	117.1±4.0	129.8	**
ICC 8522	76.5±3.5	45.3±1.8	88.5±3.5	58.4±1.6	67.2	204.1±31.4	137±3.4	117.4±21.5	141.4±4.0	150.0	**
ICC 11944	53.2±3.5	39.0±1.8	65.1±3.5	37.6±1.6	48.7	186.9±31.4	67.7±3.4	89.7±21.5	98.3±4.0	110.6	**
ICC 9862	56.4±3.5	50.1±1.8	73.8±4.1	64.0±1.6	61.1	208.6±31.4	233.4±3.4	99.3±25.2	168.6±4.0	177.5	**
ICC 791	54.5±3.5	35.7±1.8	55.5±3.5	62.8±1.6	52.1	189.3±31.4	78.2±3.4	119.7±21.5	182.8±4.0	142.5	**
ICC 9002	59.6±3.5	38.6±1.8	68.9±3.5	53.3±1.6	55.1	178.6±31.4	75.4±3.4	79.9±21.5	76.2±4.0	102.5	**
Mean	62.2	47.2	80.3	56.9	61.7	210.0	125.3	121.3	110.9	141.9	
Minimum	49.9	35.7	55.5	37.6	47.7	151.3	49.0	65.7	58.9	101.1	
Maximum	76.5	59.7	97.3	75.1	72.9	321.4	346.4	190.5	247.0	244.1	

Number of Seeds Pod $^{-1}$

Genotypes and genotype by environment interactions showed highly significant ($p < 0.0001$) differences for number of seeds pod $^{-1}$ (Table 4.6). Genotypes with lower (ICC 3325, ICC 13124 and ICC 11903) and higher (ICC 1052, ICC 10685 and ICC 11198) number of seeds pod $^{-1}$ at Juja also produced lower and higher number of seeds pod $^{-1}$ at Kabete .The ranking of genotypes for number of seeds plant $^{-1}$ varied across environments. Results further showed that six and thirty eight genotypes exceeded the check varieties ICCV 00108 and ICCV 97105 for number of seeds pod $^{-1}$ respectively.

Based on overall means, the genotypes varied with respect to number of seeds pod $^{-1}$ and 13 genotypes were classified as low (< 1.4), 36 genotypes as moderate (1.4 – 1.6) and 11 genotypes as high (> 1.6). The highest number of seeds pod^{-1} was recorded in genotypes ICC 1052 (1.7), ICC 10685 (1.7), ICC 9636 (1.7), ICC 9002 (1.7) and ICC 65709 (1.7). Genotypes ICC 13124 (1.3), ICC 11903 (1.3), ICC 3325 (1.3), ICC 6877 (1.3) and ICC 4872 (1.3) recorded the lowest. The check varieties ICCV 00108 (1.6) and ICCV 97105 (1.4) were classified as moderate for number of seeds pod $^{-1}$. With respect to environment wise means, the highest number of seeds pod $^{-1}$ was recorded in short rain season Kabete (1.6) followed by long rain season Juja (1.5), short rain season Juja (1.5) and long rain season Kabete (1.4) in descending order with a grand mean of 1.5 (Table 4.6).

Total Biomass

There were highly significant ($p < 0.0001$) differences among evaluated genotypes and genotype by environment interactions for total biomass yield ha $^{-1}$ (Table 4.6). All the genotypes recorded higher biomass yield ha $^{-1}$ during long rains compared to short rain season at Juja. At Kabete, most the genotypes recorded the highest biomass yield ha $^{-1}$ in the short rain season compared to long rain season, except ICC 15614, ICC 16915, ICC 4093 and ICC 9712 and check varieties. During the long rain season all genotypes recorded higher biomass yield ha $^{-1}$ at Juja compared to Kabete. While in short rain season, many genotypes except ICC 12851, ICC 13124, ICC 4093, ICC 4463, ICC 5613 and ICC 8522 recorded higher biomass yield ha $^{-1}$ at Kabete compared to Juja. Thirteen and six genotypes out-yielded the check varieties ICCV 00108 and ICCV 97105 for biomass ha $^{-1}$ respectively.

On the basis of overall means, there was highly significant difference among genotypes or total biomass yield ha $^{-1}$. Nineteen genotypes were classified as low (< 3.0 ton), 28 as moderate (3.0 - 4.0 ton) and 13 genotypes as high (> 4.0 ton). Genotype ICC 9636 gave the highest biomass yield ha $^{-1}$ (5.0 ton) followed by ICC 4463 (4.9 ton), ICC 5639 (4.9 ton), ICC 7867 (4.8 ton), ICC 4182 (4.8 ton) and ICC 1052 (4.8 ton). While genotypes ICC 1398 (2.1 ton), ICC 8522 (2.1 ton) ICC 9002 (2.2 ton), ICC 791 (2.2 ton) and ICC 12851 (2.2 ton) recorded the lowest biomass yield. Based on the environment wise means, the highest biomass yield ha $^{-1}$ was recorded during the long rain season at Juja (4.5 ton) followed by short rain season Kabete (3.8 ton) , short rain season Juja (2.7 ton) and long rain season Kabete (2.5 ton) with a grand mean of 3.4 ton ha $^{-1}$.

Table 4.6: Performance of *Desi* Genotypes for Number of Seeds Pod $^{-1}$ and Total Biomass ha $^{-1}$ at Juja and Kabete

	Number of Seeds Pods^{-1}					Total Biomass in tons ha $^{-1}$					
	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Pr.
ICC 9636	1.7±0.1	1.4±0.1	1.7±0.1	1.9±0.1	1.7	7.4±0.7	3.2±0.7	4.5±0.4	5.1±0.3	5.0	**
ICCV 97105 (Check)	1.4±0.1	1.4±0.1	1.3±0.1	1.6±0.1	1.4	6.7±0.8	3.1±0.7	4.1±0.4	4.0±0.3	4.5	**
ICCV 00108 (Check)	1.6±0.1	1.6±0.1	1.4±0.1	1.8±0.1	1.6	5.2±0.7	2.3±0.7	4.5±0.4	4.2±0.3	4.0	**
ICC 6579	1.6±0.1	1.8±0.1	1.6±0.1	1.9±0.1	1.7	4.1±0.8	3.5±0.7	2.5±0.4	6.9±0.3	4.3	**
ICC 5639	1.6±0.1	1.7±0.1	1.6±0.1	1.6±0.1	1.6	5.7±0.7	3.3±0.7	3.5±0.4	7.1±0.3	4.9	**
ICC 1052	1.7±0.1	1.7±0.1	1.7±0.1	1.8±0.1	1.7	5.2±0.8	4.7±0.7	2.2±0.4	6.9±0.3	4.8	**
ICC 15614	1.3±0.1	1.4±0.1	1.4±0.1	1.7±0.1	1.4	5.4±0.7	2.6±0.7	3.8±0.4	3.2±0.3	3.7	**
ICC 3325	1.2±0.1	1.3±0.1	1.2±0.1	1.4±0.1	1.3	6.0±0.7	2.7±0.7	3.0±0.4	4.0±0.3	3.9	**
ICC 16915	1.3±0.1	1.5±0.1	1.4±0.1	1.5±0.1	1.4	5.0±0.7	2.8±0.7	3.6±0.4	3.2±0.3	3.6	**
ICC 4182	1.6±0.1	1.4±0.1	1.5±0.1	1.6±0.1	1.5	4.6±0.7	4.9±0.7	2.3±0.4	7.3±0.3	4.8	**
ICC 7867	1.5±0.1	1.6±0.1	1.5±0.1	1.6±0.1	1.6	6.1±0.8	4.9±0.7	1.6±0.4	6.5±0.3	4.8	**
ICC 1356	1.4±0.1	1.7±0.1	1.4±0.1	1.5±0.1	1.5	3.9±0.7	2.4±0.7	2.5±0.4	3.5±0.3	3.1	**
ICC 1422	1.3±0.1	1.6±0.1	1.4±0.1	1.4±0.1	1.4	5.8±0.7	2.5±0.7	2.8±0.4	4.2±0.3	3.8	**
ICC 4093	1.6±0.1	1.4±0.1	1.4±0.1	1.7±0.1	1.5	5.3±0.7	3.6±0.7	4.0+0.4	3.2±0.3	4.0	**
ICC 16261	1.6±0.1	1.3±0.1	1.5±0.1	1.7±0.1	1.5	6.0±0.7	3.0±0.7	3.5±0.4	4.7±0.3	4.3	**
ICC 1715	1.5±0.1	1.5±0.1	1.4±0.1	1.7±0.1	1.5	5.1±0.7	3.1±0.7	3.4±0.4	4.8±0.3	4.1	**
ICC 8318	1.3±0.1	1.6±0.1	1.4±0.1	1.5±0.1	1.4	5.2±0.8	2.7±0.7	2.7±0.4	3.1±0.3	3.4	**
ICC 2580	1.4±0.1	1.6±0.1	1.4±0.1	1.4±0.1	1.5	4.3±0.7	2.1±0.7	2.0±0.4	3.8±0.3	3.0	**
ICC 16524	1.5±0.1	1.4±0.1	1.3±0.1	1.6±0.1	1.4	5.3±0.8	2.0±0.7	2.3±0.4	3.1±0.3	3.2	**
ICC 4463	1.6±0.1	1.4±0.1	1.5±0.1	1.8±0.1	1.6	5.8±0.8	5.4±0.7	3.2±0.4	5.3±0.3	4.9	**
ICC 1392	1.5±0.1	1.5±0.1	1.4±0.1	1.6±0.1	1.5	4.7±0.7	2.5±0.7	2.4±0.4	4.3±0.3	3.5	**
ICC 5504	1.4±0.1	1.4±0.1	1.3±0.1	1.5±0.1	1.4	5.4±0.7	3.7±0.7	3.3±0.4	4.9±0.3	4.3	**
ICC 9872	1.4±0.1	1.6±0.1	1.6±0.1	1.4±0.1	1.5	4.5±0.7	3.3±0.7	2.6±0.4	3.9±0.3	3.6	**
ICC 2242	1.3±0.1	1.5±0.1	1.3±0.1	1.4±0.1	1.4	5.2±0.7	2.7±0.7	3.0±0.4	3.8±0.3	3.7	**
ICC 1510	1.3±0.1	1.4±0.1	1.4±0.1	1.2±0.1	1.3	4.1±0.7	2.8±0.7	2.1±0.4	4.6±0.3	3.4	**
ICC 12928	1.5±0.1	1.5±0.1	1.6±0.1	1.8±0.1	1.6	5.6±0.7	3.2±0.7	3.3±0.4	5.4±0.3	4.4	**
Annigeri©	1.5±0.2	1.5±0.2	1.4±0.2	1.6+0.2	1.5	4.5±1.2	2.7±1.2	2.4±1.2	3.8±1.2	3.4	**
ICC 8200©	1.5±0.2	1.5±0.2	1.4±0.2	1.6±0.2	1.5	4.5±1.2	2.7±1.2	2.4±1.2	3.8±1.2	3.4	**
ICC 4918©	1.5±0.2	1.5±0.2	1.4±0.2	1.6±0.2	1.5	4.5±1.2	2.7±1.2	2.4±1.2	3.8±1.2	3.4	**
ICC 6294©	1.5±0.2	1.5±0.2	1.4±0.2	1.6±0.2	1.5	4.5±1.2	2.7±1.2	2.4±1.2	3.8±1.2	3.4	**

Continue Table 4.6

ICCV 07102©	1.5±0.2	1.5±0.2	1.4±0.2	1.6±0.2	1.5	4.5±1.2	2.7±1.2	2.4±1.2	3.8±1.2	3.4	**
ICCV 00104©	1.5±0.2	1.5±0.2	1.4±0.2	1.6±0.2	1.5	4.5±1.2	2.7±1.2	2.4±1.2	3.8±1.2	3.4	**
ICC 10685	1.7±0.1	1.8±0.1	1.7±0.1	1.8±0.1	1.7	3.6±0.8	2.5±0.7	2.3±0.4	2.9±0.3	2.8	**
ICC 7413	1.4±0.1	1.5±0.1	1.2±0.1	1.1±0.1	1.3	3.7±0.8	2.5±0.7	2.6±0.4	3.9±0.3	3.2	**
ICCV 10	1.5±0.1	1.3±0.1	1.3±0.1	1.4±0.1	1.4	4.4±0.7	2.0±0.7	1.8±0.4	3.2±0.3	2.8	**
ICC 7326	1.5±0.1	1.4±0.1	1.4±0.1	1.7±0.1	1.5	5.9±0.8	3.1±0.7	3.0±0.4	4.9±0.3	4.2	**
ICC 9712	1.4±0.1	1.3±0.1	1.4±0.1	1.8±0.1	1.5	5.1±0.7	2.7±0.7	3.2±0.4	2.9±0.3	3.5	**
ICC 14815	1.4±0.1	1.6±0.1	1.2±0.1	1.7±0.1	1.5	3.9±0.8	2.5±0.7	3.2±0.4	3.6±0.3	3.3	**
ICC 4657	1.6±0.1	1.4±0.1	1.6±0.1	1.6±0.1	1.5	4.9±0.7	2.2±0.7	1.4±0.4	3.5±0.3	3.0	**
ICC 1164	1.5±0.1	1.4±0.1	1.6±0.1	1.5±0.1	1.5	4.1±0.7	2.3+0.7	2.5±0.4	2.7±0.3	2.9	**
ICC 14051	1.5±0.1	1.6±0.1	1.3±0.1	1.5±0.1	1.5	4.4±0.7	2.3±0.7	2.1±0.4	4.5±0.3	3.3	**
ICC 12851	1.5±0.1	1.4±0.1	1.4±0.1	1.6±0.1	1.5	3.5±0.7	2.0±0.7	1.7±0.4	1.5±0.3	2.2	**
ICC 4991	1.5±0.1	1.4±0.1	1.5±0.1	1.7±0.1	1.5	2.7±0.8	1.8±0.7	3.1±0.4	2.9±0.3	2.6	**
ICC 506	1.3±0.1	1.5±0.1	1.3±0.1	1.5±0.1	1.4	4.6±0.7	1.5±0.7	2.3±0.4	2.6±0.3	2.7	**
ICC 9702	1.4±0.1	1.3±0.1	1.5±0.1	1.5±0.1	1.4	4.2±0.7	3.1±0.7	1.2±0.4	3.5±0.3	3.0	**
ICCV 07111	1.6±0.1	1.5±0.1	1.6±0.1	1.7±0.1	1.6	3.1±0.7	2.2±0.7	1.1±0.4	3.7±0.3	2.5	**
ICC 1398	1.4±0.1	1.5±0.1	1.5±0.1	1.4±0.1	1.5	3.7±0.7	1.6±0.7	1.0±0.4	1.9±0.3	2.1	**
ICC 13124	1.3±0.1	1.5±0.1	1.2±0.1	1.2±0.1	1.3	3.5±0.7	2.5±0.7	1.7±0.4	2.1±0.3	2.5	**
ICC 6877	1.3±0.1	1.4±0.1	1.2±0.1	1.1±0.1	1.3	4.9±0.8	2.7±0.7	2.0±0.4	3.0±0.3	3.2	**
ICC 4872	1.2±0.1	1.2±0.1	1.3±0.1	1.4±0.1	1.3	3.8±0.7	2.4±0.7	1.3±0.4	2.9±0.3	2.6	**
ICC 11198	1.7±0.1	1.8±0.1	1.6±0.1	1.6±0.1	1.7	3.0±0.7	2.0±0.7	1.3±0.4	3.3±0.3	2.4	**
ICC 5613	1.3±0.1	1.4±0.1	1.4±0.1	1.6±0.1	1.4	2.9±0.7	2.4±0.7	2.3±0.4	2.3±0.3	2.5	**
ICC 9895	1.5±0.1	1.5±0.1	1.3±0.1	1.5±0.1	1.4	4.0±0.8	3.2±0.7	2.0±0.4	3.8±0.3	3.2	**
ICC 11903	1.3±0.1	1.6±0.1	1.2±0.1	1.1±0.1	1.3	3.5±0.7	2.6±0.7	1.8±0.4	3.3±0.3	2.8	**
ICC 1397	1.3±0.1	1.5±0.1	1.2±0.1	1.5+0.1	1.4	3.4±0.8	1.6±0.7	0.7±0.4	3.5±0.3	2.3	**
ICC 8522	1.5±0.1	1.4±0.1	1.5±0.1	1.8±0.1	1.5	2.9±0.7	2.0±0.7	1.6±0.4	1.7±0.3	2.1	**
ICC 11944	1.5±0.1	1.3±0.1	1.7±0.1	1.7±0.1	1.5	3.0±0.8	1.8±0.7	1.4±0.4	2.7±0.3	2.3	**
ICC 9862	1.4±0.1	1.2±0.1	1.5±0.1	1.5±0.1	1.4	3.1±0.7	3.1±0.7	0.9±0.4	3.5±0.3	2.7	**
ICC 791	1.6±0.1	1.7±0.1	1.7±0.1	1.6±0.1	1.6	3.0±0.7	1.3±0.7	1.2±0.4	3.4±0.3	2.2	**
ICC 9002	1.6±0.1	1.6±0.1	1.6±0.1	2.0±0.1	1.7	3.5±0.7	2.2±0.7	1.0±0.4	1.9±0.3	2.2	**
Mean	1.5	1.5	1.4	1.6	1.5	4.5	2.7	2.4	3.8	3.4	
Minimum	1.2	1.2	1.2	1.1	1.3	2.7	1.3	0.7	1.5	2.1	
Maximum	1.7	1.8	1.7	1.9	1.7	7.4	5.4	4.5	7.3	5.0	

Seed Yield

The genotypes and genotype by environment interactions displayed highly significant differences ($p < 0.0001$) for seed yield ha $^{-1}$ (Table 4.7). Most evaluated genotypes recorded higher seed yield ha $^{-1}$ during long rains compared to short rains at both sites except genotypes ICC 1356, ICC 1387, ICC 1398, ICC 16524, ICC 6579 and ICC 7867 which recorded higher during short rain season at Kabete. During the long rain season many genotypes gave higher yield ha $^{-1}$ at Juja compared to Kabete. While in short rain season higher seed yield ha $^{-1}$ were recorded at Kabete except ICC 1052, ICC 11903, ICC 12851, ICC 13124, ICC 1392, ICC 2242, ICC 2580, ICC 4182, ICC 5504, ICC 6877 and ICC 7867 which recorded higher in Juja. The ranking of genotypes for seed yield ha $^{-1}$ varied across environments.

Based on overall means, genotype ICC 9636 gave the highest seed yield ha $^{-1}$ (1.8 ton) followed by check varieties ICCV 97105 (1.8 ton), ICCV 00108 (1.8 ton), genotypes ICC 6579 (1.7 ton) and ICC 5639 (1.7 ton). Genotypes ICC 3325 (1.6 ton), ICC 15614 (1.6 ton), ICC 1052 (1.6 ton), ICC 5639 (1.7 ton), ICC 6579 (1.7 ton), ICCV 00108 (1.8 ton), ICCV 97105 (1.8 ton) and ICC 9636 (1.8 ton) recorded equal or greater than 1.6 ton ha $^{-1}$ for mean seed yield ha $^{-1}$. The lowest seed yield ha $^{-1}$ was recorded for genotypes ICC 9002 (0.9 ton), ICC 791 (0.9 ton), ICC 9862 (0.9 ton) ICC 1397 (0.9 ton), ICC 8522 (0.9 ton) and ICC (11944 (0.9 ton). Based on the environment wise means, the highest seed yield ha $^{-1}$ was recorded in the long rain season Juja (2.1 ton) followed by long rain season Kabete (1.3 ton), short rain season Kabete (1.1 ton) and short rain season Juja (0.8 ton) with a grand mean of 1.3 ton.

Hundred Seed Weight

There were highly significant ($p < 0.0001$) differences among genotypes and genotype by environment interactions for 100 seed weight (Table 4.7). The studied genotypes except the check varieties which recorded higher 100 seed weight in the short rain compared to long rain season at Kabete. While at Juja, 42.0 % of the evaluated the genotypes recorded higher 100 seed weight during the long rain season. During the long rain seasons, most genotypes except check varieties recorded higher 100 seed weight at Juja compared to Kabete. Three genotypes exceeded the check varieties ICCV 00108 and ICCV 97105 for 100 seed weight.

Based on overall means, there were wide differences among genotypes with respect to 100 seed weight. Twenty eight genotypes were categorized as low (< 22 g), 22 as moderate (22.0 – 25.0 g) and 10 genotypes as high (> 25 g) for 100 seed weight. Genotype ICC 13124 (33.8 g) followed by ICC 6877 (28.6 g), ICC 11903 (28.1 g) and ICCV 07111 (26.2 g) recorded the highest 100 seed weight. While genotypes ICC 5639 (18.2 g), ICC 4991 (19.1 g), ICC 1052 (19.1 g) and ICC 4093 (19.3 g) were the lowest for seed weight. The check varieties ICCV 00108 (26.2 g) and ICCV 97105(26.2 g) were classified in the high seed weight category. With respect to environment wise means, the highest 100 seed weight was recorded in the short rain season Kabete (24.5 g) followed by short rain season Juja (23.3 g), long rain season Juja (22.4 g) and long rain season Kabete (20.3 g) with a grand mean of 22.6 g .

Table 4.7: Performance of *Desi* Genotypes for Seed Yield ha $^{-1}$ and Hundred Seed Weight at Juja and Kabete

	Seed Yield in tons ha $^{-1}$					Hundred Seed Weight in grams					
	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Pr.
ICC 9636	3.2±0.3	0.8±0.2	2.1±0.3	1.3±0.3	1.8	20.1±0.9	21.0±0.7	17.1±1.0	23.9±0.6	20.6	**
ICCV 97105 (Check)	2.8±0.3	0.9±0.2	2.1±0.3	1.4±0.2	1.8	27.7±0.9	25.4±0.7	28.9±1.0	22.8±0.6	26.2	**
ICCV 00108 (Check)	2.5±0.3	0.9±0.2	2.3±0.3	1.4±0.2	1.8	28.0±0.9	21.3±0.7	29.3±1.0	26.4±0.6	26.2	**
ICC 6579	2.7±0.3	1.2±0.2	1.5±0.3	1.6±0.2	1.7	20.0±0.9	22.7±0.7	17.2±1.0	23.9±0.6	20.9	**
ICC 5639	2.5±0.3	1.1±0.2	1.8±0.3	1.3±0.2	1.7	18.5±0.9	19.5±0.7	15.5±1.0	19.3±0.6	18.2	**
ICC 1052	2.3±0.3	1.6±0.2	1.3±0.3	1.3±0.2	1.6	18.8±0.9	22.3±0.7	17.5±1.0	18.0±0.6	19.1	**
ICC 15614	2.5±0.3	0.7±0.2	2.0±0.3	1.4±0.2	1.6	20.1±0.9	21.2±0.7	18.5±1.0	28.0±0.6	22.0	**
ICC 3325	2.8±0.3	0.8±0.2	1.5±0.3	1.4±0.2	1.6	22.0±0.9	22.2±0.7	19.8±1.0	22.1±0.6	21.5	**
ICC 16915	2.5±0.3	0.9±0.2	1.7±0.3	1.3±0.2	1.6	24.5±0.9	26.5±0.7	23.0±1.0	25.1±0.6	24.8	**
ICC 4182	2.1±0.3	1.6±0.2	1.3±0.3	1.4±0.3	1.6	21.3±0.9	26.5±0.7	16.4±1.0	20.6±0.6	21.2	**
ICC 7867	2.3±0.3	1.5±0.2	1.1±0.3	1.4±0.2	1.6	23.8±0.9	20.8±0.7	21.2±1.0	26.2±0.6	23.0	**
ICC 1356	2.2±0.3	0.7±0.2	1.5±0.3	1.9±0.2	1.6	22.2±0.9	21.1±0.7	20.2±1.0	22.6±0.6	21.5	**
ICC 1422	2.6±0.3	0.8±0.2	1.8±0.3	1.1±0.2	1.6	24.3±0.9	22.2±0.7	22.2±1.0	29.7±0.6	24.6	**
ICC 4093	2.5±0.3	0.9±0.2	1.7±0.3	1.1±0.2	1.5	17.7±0.9	22.2±0.7	15.1±1.2	22.1±0.6	19.3	**
ICC 16261	2.4±0.3	0.6±0.2	1.7±0.3	1.5±0.2	1.5	19.7±0.9	25.3±0.7	17.5±1.0	23.2±0.6	21.4	**
ICC 1715	2.6±0.3	0.6±0.2	1.8±0.3	1.2±0.2	1.5	20.1±0.9	21.5±0.7	17.7±1.0	22.0±0.6	20.3	**
ICC 8318	2.3±0.3	1.0±0.2	1.5±0.3	1.1±0.2	1.5	24.9±0.9	18.9±0.7	23.2±1.0	30.1±0.6	24.3	**
ICC 2580	2.2±0.3	0.6±0.2	1.6±0.3	1.5±0.2	1.5	25.8±0.9	22.9±0.7	23.5±1.0	26.4±0.6	24.7	**
ICC 16524	2.2±0.3	0.7±0.2	1.3±0.3	1.4±0.3	1.4	21.1±0.9	25.1±0.7	20.4±1.0	25.7±0.6	23.1	**
ICC 4463	1.9±0.3	1.2±0.2	1.7±0.3	0.8±0.2	1.4	18.4±0.9	22.8±0.7	18.5±1.0	19.5±0.6	19.8	**
ICC 1392	2.2±0.3	0.7±0.2	1.3±0.3	1.2±0.2	1.4	24.8±0.9	21.7±0.7	27.8±1.0	29.4±0.6	25.9	**
ICC 5504	2.1±0.3	0.9±0.2	1.6±0.3	0.8±0.2	1.4	25.6±0.9	21.8±0.7	26.3±1.0	28.3±0.6	25.5	**
ICC 9872	2.0±0.3	0.9±0.2	1.4±0.3	1.1±0.2	1.3	23.9±0.9	23.4±0.7	21.3±1.0	26.9±0.6	23.9	**
ICC 2242	2.2±0.3	0.8±0.2	1.6±0.3	0.7±0.2	1.3	20.2±0.9	24.3±0.7	17.5±1.0	24.2±0.6	21.5	**
ICC 1510	2.0±0.3	0.9±0.2	1.3±0.3	1.2±0.2	1.3	23.1±0.9	25.3±0.7	21.5±1.0	28.1±0.6	24.5	**
ICC 12928	2.4±0.3	0.5±0.2	1.5±0.3	0.9±0.2	1.3	21.1±0.9	26.1±0.7	17.8±1.0	21.7±0.6	21.7	**
Annigeri©	2.1±0.4	0.8±0.4	1.3±0.4	1.0±0.4	1.3	22.4±3.7	23.3±3.7	20.3±3.7	24.5±3.7	22.6	**
ICC 8200©	2.1±0.4	0.8±0.4	1.3±0.4	1.0±0.4	1.3	22.4±3.7	23.3±3.7	20.3±1.0	24.5±3.7	22.6	**
ICC 4918©	2.1±0.4	0.8±0.4	1.3±0.4	1.0±0.4	1.3	22.4±3.7	23.3±3.7	20.3±3.7	24.5±3.7	22.6	**

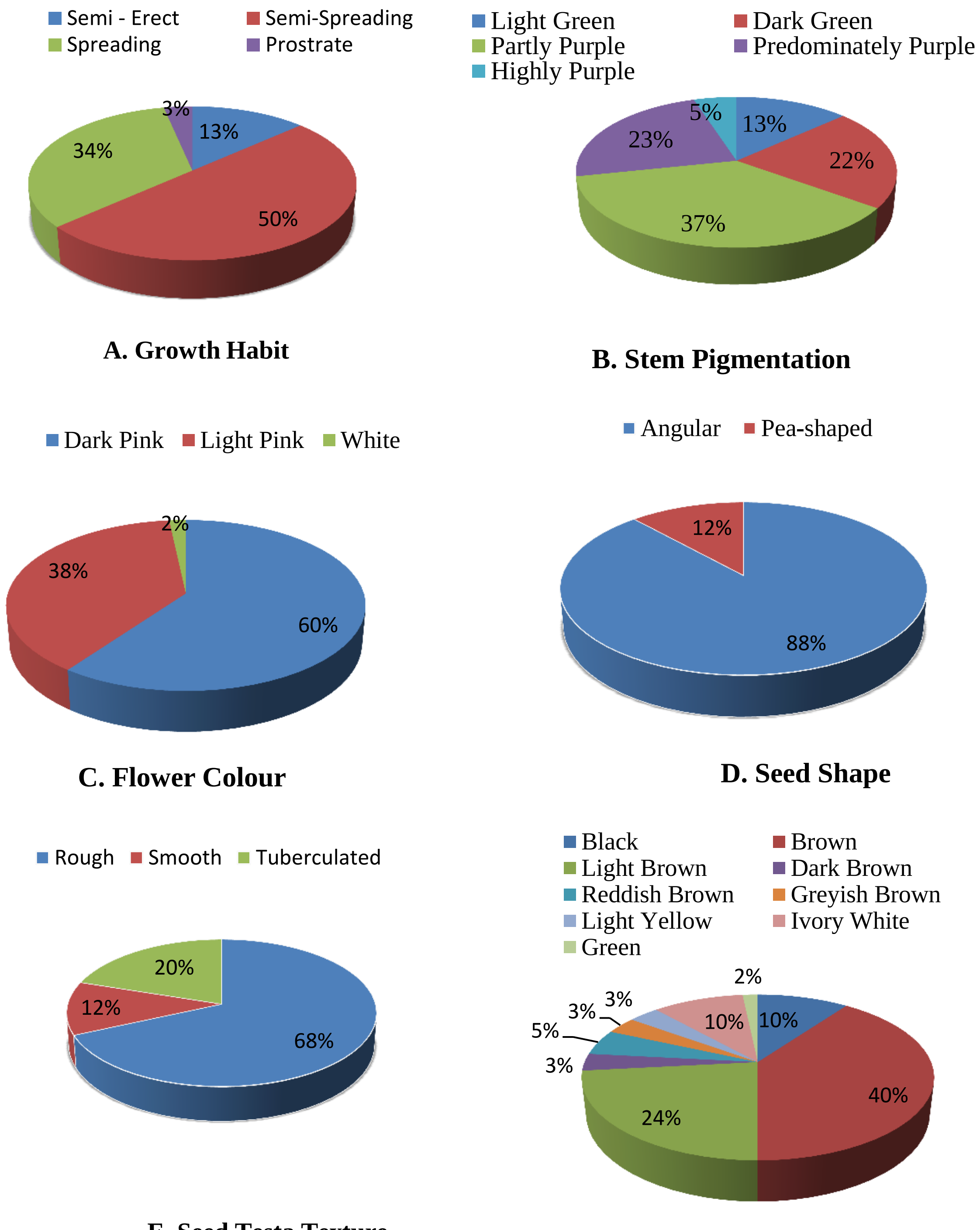
Continue Table 4.7

ICC 6294©	2.1±0.4	0.8±0.4	1.3±0.4	1.0±0.4	1.3	22.4±3.7	23.3±3.7	20.3±3.7	24.5±3.7	22.6	**
ICCV 07102©	2.1±0.4	0.8±0.4	1.3±0.4	1.0±0.4	1.3	22.4±3.7	23.3±3.7	20.3±3.7	24.5±3.7	22.6	**
ICCV 00104©	2.1±0.4	0.8±0.4	1.3±0.4	1.0±0.4	1.3	22.4±3.7	23.3±3.7	20.3±3.7	24.5±3.7	22.6	**
ICC 10685	1.9±0.3	1.0±0.2	1.2±0.3	1.1±0.2	1.3	17.1±0.9	26.5±0.7	15.3±1.2	23.2±0.6	20.5	**
ICC 7413	1.7±0.3	0.8±0.2	1.4±0.3	1.3±0.2	1.3	23.1±1.1	19.8±0.7	23.2±1.0	27.3±0.6	23.3	**
ICCV 10	2.2±0.3	0.8±0.2	1.1±0.3	1.1±0.2	1.3	25.3±0.9	24.6±0.7	24.1±1.0	28.4±0.6	25.6	**
ICC 7326	2.1±0.3	0.7±0.2	1.4±0.3	0.8±0.2	1.2	22.7±0.9	21.3±0.7	21.6±1.0	22.8±0.6	22.1	**
ICC 9712	2.0±0.3	0.6±0.2	1.3±0.3	1.1±0.2	1.2	19.4±0.9	25.3±0.7	16.3±1.0	20.6±0.6	20.4	**
ICC 14815	1.7±0.3	0.5±0.2	1.4±0.3	1.3±0.2	1.2	21.6±0.9	23.6±0.7	19.3±1.0	23.7±0.6	22.1	**
ICC 4657	2.1±0.3	0.9±0.2	0.9±0.3	0.9±0.2	1.2	18.3±0.9	23.0±0.7	15.1±1.0	23.3±0.6	19.9	**
ICC 1164	2.2±0.3	0.5±0.2	1.3+0.3	0.9±0.2	1.2	20.4±0.9	31.5±0.7	17.5±1.0	22.0±0.6	22.9	**
ICC 14051	2.1±0.3	0.8±0.2	1.2±0.3	0.9±0.2	1.2	19.8±0.9	19.7±0.7	16.7±1.0	22.6±0.6	19.7	**
ICC 12851	2.1±0.3	0.8±0.2	1.1±0.3	0.7±0.2	1.2	18.9±0.9	23.2±0.7	16.6±1.0	22.7±0.6	20.4	**
ICC 4991	1.6±0.3	0.5±0.2	1.5±0.3	1.0±0.2	1.1	19.3±0.9	19.8±0.7	16.4±1.0	21.0±0.6	19.1	**
ICC 506	2.1±0.3	0.5±0.2	1.2±0.3	0.8±0.2	1.1	23.4±0.9	20.0±0.7	21.9±1.0	26.0+0.6	22.8	**
ICC 9702	1.9±0.3	0.8±0.2	0.9±0.3	0.9±0.2	1.1	22.2±0.9	22.4±0.7	18.3±1.0	24.0±0.6	21.7	**
ICCV 07111	1.7±0.3	0.7±0.2	0.9±0.3	1.3±0.2	1.1	26.1±0.9	25.5±0.7	24.9±1.0	28.4±0.6	26.2	**
ICC 1398	1.9±0.3	0.8±0.2	0.8±0.3	0.9±0.2	1.1	24.5±0.9	24.2±0.7	21.0±1.0	26.3±0.6	24.0	**
ICC 13124	1.9±0.3	0.9±0.2	1.0±0.3	0.7±0.2	1.1	34.7±0.9	29.9±0.7	34.5±1.0	36.1±0.6	33.8	**
ICC 6877	2.0±0.3	0.6±0.2	1.0±0.3	0.5±0.2	1.0	28.8±0.9	28.6±0.7	27.7±1.0	29.3±0.6	28.6	**
ICC 4872	1.8±0.3	0.6±0.2	0.9±0.3	.8±0.2	1.0	26.6±0.9	23.0±0.7	25.1±1.0	27.4±0.6	25.5	**
ICC 11198	1.7±0.3	0.4±0.2	0.9±0.3	0.9±0.2	1.0	20.3±0.9	22.0±0.7	19.8±1.0	22.4±0.6	21.1	**
ICC 5613	1.5±0.3	0.5±0.2	1.2±0.3	0.7±0.2	1.0	23.6±0.9	19.1±0.7	21.3±1.0	24.2±0.6	22.0	**
ICC 9895	1.7±0.3	0.4±0.2	0.9±0.3	0.8±0.2	1.0	21.3±1.1	18.6±0.7	19.0±1.2	22.5±0.6	20.4	**
ICC 11903	1.6±0.3	0.8±0.2	0.9±0.3	0.5±0.2	1.0	32.2±0.9	26.8±0.7	25.3±1.0	28.0±0.6	28.1	**
ICC 1397	1.7±0.3	0.4±0.2	0.7±0.3	0.9±0.2	0.9	23.8±1.1	21.6±0.7	13.3±1.2	21.8±0.6	20.1	**
ICC 8522	1.6±0.3	0.5±0.2	1.0±0.3	0.6±0.2	0.9	20.3±0.9	27.2±0.7	18.4±1.0	23.2±0.6	22.3	**
ICC 11944	1.5±0.3	0.5±0.2	0.9±0.3	0.9±0.2	0.9	17.5±0.9	26.0±0.7	15.8±1.0	26.1±0.6	21.4	**
ICC 9862	1.5±0.3	0.6±0.2	0.7±0.3	0.7±0.2	0.9	22.6±0.9	20.1±0.7	19.8±1.2	22.2±0.6	21.2	**
ICC 791	1.6±0.3	0.4±0.2	0.8±0.3	0.6±0.2	0.9	19.5±0.9	24.0±0.7	16.9±1.0	21.1±0.6	20.4	**
ICC 9002	1.7±0.3	0.5±0.2	0.7±0.3	0.5±0.2	0.9	20.2±0.9	25.6±0.7	16.6±1.0	21.2±0.6	20.9	**
Mean	2.1	0.8	1.3	1.0	1.3	22.4	23.3	20.3	24.5	22.6	
Minimum	1.5	0.4	0.7	0.5	0.9	17.1	18.6	13.3	18.0	18.2	
Maximum	3.2	1.6	2.4	1.9	1.8	34.7	31.5	34.5	36.1	33.8	

4.1.3. Qualitative Characters of *Desi* Chickpea

Eight qualitative traits showed wide differences among genotypes (Figure 4.1) for all studied characters except leaf type and pod dehiscence for which the genotypes were monomorphic. Genotypes recorded four types of growth habit namely semi erect, semi- spreading, spreading and prostrate. Semi spreading (50 %) was the most predominant among the genotypes followed by spreading (34.0 %) and semi- erect (13.0 %) while prostrate recorded the lowest (3.0 %) (Figure 4.1A). Genotypes varied with respect to stem pigmentation and showed 5 types. Majority of genotypes recorded partly purple stem colour (37.0 %) followed by predominately purple (23.0 %) and dark green (22.0 %) while the minimum frequency recorded for highly purple (5.0 %) and light green (13.0 %) (Figure 4.1B). Genotypes differed in flower colour, which included dark pink (60.0 %), light pink (38.0 %) and white (2.0 %) (Figure 4.1C). Genotypes further varied with respect to seed shape such as angular (88 %) and pea-shaped (12 %) (Figure 4.1D), for seed testa texture like rough (68 %), tuberculated (20 %) and smooth (12 %) (Figure 4.1E).

The studied genotypes showed substantial differences for seed coat colour that varied from brown to green. The maximum frequency was recorded for brown (40.0 %) followed by light brown (24.0 %), black (10.0 %) and ivory white (10.0 %) while green (2.0 %) recorded the lowest frequency (Figure 4.1F).



A. Growth Habit

B. Stem Pigmentation

C. Flower Colour

D. Seed Shape

E. Seed Testa Texture

F. Seed Coat Colour

Figure 4.1: Distribution of Qualitative Traits among *Desi* Chickpea at Juja and Kabete

4.1.4. Correlation among Quantitative Characters of *Desi* Genotypes

Correlation coefficients among quantitative traits across sites are presented in (Table 4.8). While results on environment wise correlation are given in appendices (III, IV, V, and VI).

Results on across environments data indicated that seed yield ha $^{-1}$ showed positive and significant ($p < 0.05$) correlation with total biomass yield ha $^{-1}$ (r = 0.80 **), pod filling period (r = 0.34**), number of pods plant $^{-1}$ (r = 0.31*), number of primary branches plant $^{-1}$ (r = 0.28*) and number of secondary branches plant $^{-1}$ (r = 0.25*). Seed yield ha $^{-1}$ correlated negatively significant with days to 50 % flowering (r = - 0.27*) and days to 50 % podding (r = - 0.30*), but non-significantly correlated with other traits.

There was positive and highly significant ($p < 0.01$) correlation of total biomass yield ha $^{-1}$ with number of primary branches plant $^{-1}$ (r = 0.60**), number of secondary branches plant $^{-1}$ (r = 0.57**), number of pods plant $^{-1}$(r = 0.53**), days to 75 % maturity (r = 0.42**), plant height (r = 0.38**) and plant canopy width (r = 0.35**) But biomass yield ha $^{-1}$ was not significantly correlated with the other traits.

The number of pods plant $^{-1}$ was correlated positively and significantly ($p < 0.05$) with plant canopy width (r = 0.53**), plant height (r = 0.46**), number of primary (r = 0.47**) and secondary (r = 0.57**) branches plant $^{-1}$, days to 75 % maturity (r = 0.44**) and pod filling period (r = 0.30*).

Days to 75 % maturity was positively and highly significant correlated ($p < 0.01$) with days to 50 % flowering (r = 0.50**), days to 50 % podding (r = 0.44**), plant canopy width (r = 0.51**), plant height (r = 0.44**), number of primary branches plant $^{-1}$ (r = 0.44**) and number of secondary branches plant $^{-1}$ (r = 0.46**).

The results further showed positive and highly significant ($p < 0.01$) correlation of days to 50 % podding with days to 50 % flowering (r = 0.92**), plant height with plant canopy width (r = 0.89**).

Table 4.8: Correlation Coefficient among Quantitative Characters of *Desi* Genotypes at Juja and Kabete

Characters	DF	DP	PCW	PH	NPB	NSB	DM	PFP	NPP $^{-1}$	NSP $^{-1}$	BM	SY	HSW
DF	1												
DP	0.92**	1											
PCW	0.07 NS	-0.01NS	1										
PH	0.05NS	-.0.04NS	0.89**	1									
NPB	0.43**	0.39**	0.19NS	0.21NS	1								
NSB	0.44**	0.41**	0.31*	0.29*	0.80**	1							
DM	0.50**	0.44**	0.51**	0.44**	0.44**	0.46**	1						
PFP	-0.81**	-0.75**	0.27*	0.25*	-0.17NS	-0.20NS	0.11NS	1					
NPP $^{-1}$	0.00NS	-0.04NS	0.53**	0.46**	0.47**	0.57**	0.44**	0.30*	1				
NSP $^{-1}$	0.18NS	0.13NS	-0.15NS	-0.14NS	0.12NS	0.03NS	0.16NS	-0.09NS	0.03NS	1			
BM	0.12NS	0.07NS	0.35**	0.38**	0.60**	0.57**	0.42**	0.15NS	0.53**	0.22NS	1		
SY	-0.27*	-0.30*	0.04NS	0.10NS	0.28*	0.25*	0.05NS	0.34**	0.31*	0.21NS	0.80**	1	
HSW	-0.22NS	0.16NS	0.04NS	0.20NS	-0.28*	-0.23NS	-0.19NS	0.11NS	-0.19NS	-0.55**	-0.17NS	-0.04NS	1

Note: **- significant at 1 % level of significant (Pr < 0.01), * - significant at 5 % level of significant (Pr < 0.05) and NS – non - significant at 5 % (Pr > 0.05)

DF- days to 50 % flowering, DP - days to 50 % podding , PCW - plant canopy width , PH - plant height, NPB - number of primary branches plant $^{-1}$, NSB - number of secondary branches plant $^{-1}$, DM - days to 75% maturity, PFP- pod filling period, NPP $^{-1}$ - number of pods plant $^{-1}$,NSP $^{-1}$ – number of seeds pod $^{-1}$, BM – Total biomass ha $^{-1}$, SY – seed yield ha^{-1} and HSW- hundred seed weight

4.2. Genetic Evaluation of *Kabuli* Chickpea Genotypes

4.2.1. Agronomic Traits

Day to 50 % Flowering

The genotypes and genotype by environment interactions showed highly significant ($p < 0.0004$) variation in their response to flowering time (Table 4.9). Most genotypes took longer time to flower in the long rain season compared to short rain season at Juja except ICC 2482.While at Kabete 71.8 % of genotypes took longer time in short rain compared to long rain season. Early (ICCV 08302, ICCV 08303 and ICCV 07308) and late (ICC 13283, ICC 13461 and IG 72109) flowering genotypes in Juja also flowered early and late at Kabete. Twenty eight and twelve genotypes flowered earlier than the check varieties ICCV 00305 and ICCV 92318 individually.

Based on overall means, the genotypes indicated wide differences in response to flowering time. Eleven genotypes were classified as early flowering (< 40 days), 19 genotypes as moderate (40 – 50 days) and 9 genotypes were late (> 50 days) in flowering. The earliest flowering genotypes were ICCV 07308 (32 days) and ICCV 08303 (32 days) followed by ICCV 08302 (33 days), ICCV 03404 (36 days) and ICCV 05312 (36 days). Genotypes ICC 13283 (65 days) and ICC 13461 (63 days) followed by IG 72109 (59 days), ICC 15802 (57 days) and K022 (57 days) were the latest. The check varieties ICCV 00305 (48 days) and ICCV 92318 (40 days) were categorized as moderate. Based on the environment wise means, the earliest in flowering was recorded in short rain season at Juja (38 days) followed by long rain season Juja (47 days), long rain season Kabete (48 days) and short rain season Kabete (48 days) with a grand mean of 45 days.

Number of Leaflet Leaf $^{-1}$ at Podding (NLLP $^{-1}$)

There were highly significant (< 0.0001) variations among genotypes and genotype by environment interactions for number of leaflet leaf $^{-1}$ at podding (Table 4.9). Evaluated genotypes recorded higher number of leaflet leaf $^{-1}$ at podding during short rains as compared to long rains at both sites. The genotypes with higher (ICC 2482, IG 72109 and ICCV 03404) and lower (ICCV 00402, ICCV 07308 and ICCV 92318) number of leaflet leaf $^{-1}$during podding at Juja also recorded higher and lower values at Kabete. The ranking of genotypes for number of leaflet leaf $^{-1}$ varied across environments. Twenty seven and thirty six genotypes exceeded the check varieties ICCV 00305 and ICCV 92318 for number of leaflet leaf $^{-1}$ respectively.

On the basis of overall means, genotypes varied with respect to number of leaflet leaf $^{-1}$ at podding. Seven genotypes were classified as low (< 13.2), 23 genotypes moderate (13.2 – 13.5) and 9 genotypes had high (> 13.5) (Table 4.9) for number of leaflet leaf $^{-1}$. Genotypes with the highest number of leaflet leaf $^{-1}$ at podding were ICCV 03404 (14.4) and ICC 2482 (14.2) followed by ICC 13461 (14.1), IG 72109 (14.0) and K025 (13.8). While the lowest number of leaflet leaf $^{-1}$ at podding was recorded in genotypes ICCV 00402 (12.4), ICCV 92318 (12.6), ICCV 07308 (12.6), ICCV 08302 (12.8) and IG 71055 (12.9) (Table 4.9).The check varieties ICCV 00305 (13.1) and ICCV 92318 (12.6) were classified as low for number of leaflet leaf $^{-1}$. With respect to environment wise means, the highest number of leaflet leaf $^{-1}$ at podding was recorded in short rain season Juja (13.6) followed by long rain season Juja (13.4) short rain season Kabete (13.4) and in long rain season Kabete (13.0) with a grand mean of 13.3.

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Table 4.9: Variation among *Kabuli* Genotypes for Days to Flowering and number of leaflet leaf $^{-1}$ at Podding at Juja and Kabete

Genotypes	Days to 50 % Flowering: Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Number of leaflet leaf $^{-1}$ at Podding: Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Pr.
ICCV 05315	38.0±3.6	30.9±1.8	44.5±4.1	48.3±1.9	40.4	13.5±0.3	13.8±0.3	13.4±0.3	13.3±0.2	13.5	**
ICC 13461	69.7±3.6	57.7±1.82	66.2±4.1	56.9±1.9	62.6	14.6±0.3	14.0±0.3	13.4±0.3	14.2±0.2	14.0	**
ICCV 07313	38.1±3.6	28.1±1.8	37.5±4.1	39.4±1.9	35.8	12.9±0.3	13.7±0.3	13.0±0.3	12.8±0.2	13.1	**
ICC 13764	58.5±3.6	50.3±1.8	54.8±4.1	50.1±1.9	53.4	13.7±0.3	14.0±0.3	12.9±0.3	14.1±0.2	13.7	**
ICCV 00302	56.3±3.6	42.5±12.1	47.1±4.1	47.6±1.9	48.4	13.5±0.3	13.4±0.3	13.2±0.3	13.5±0.2	13.4	**
ICC 2482	56.8±3.6	56.9±1.8	57.0±4.7	51.8±1.9	55.6	14.3±0.3	14.5±0.3	13.8±0.4	14.1±0.2	14.2	**
ICCV 03404	33.6±3.6	25.3±1.8	37.9±4.1	45.5±1.9	35.6	14.0±0.3	14.1±0.3	14.1±0.3	15.3±0.2	14.4	**
ICCV 00402	45.4±3.6	33.6±1.8	47.6±4.1	52.9±1.9	44.9	12.7±0.3	12.3±0.3	12.3±0.3	12.4±0.2	12.4	**
ICCV 07306	35.2±3.6	30.0±1.8	44.8±4.1	38.6±1.9	37.2	13.1±0.3	13.1±0.3	12.4±0.3	13.4±0.2	13.0	**
ICCV 00305 (Check)	52±3.6	39.7±1.8	48.0±4.1	51.3±1.9	47.7	13.3±0.3	13.2±0.3	12.9±0.3	13.2±0.2	13.1	**
ICCV 05312	32.7±3.6	25.3±1.8	41.1±4.1	43.7±1.9	35.7	13.5±0.3	13.8±0.3	13.0±0.3	13.4±0.2	13.4	**
IG 71055	66.1±3.6	57.8±1.8	56.4±4.1	42.6±1.9	55.7	13.1±0.3	12.9±0.3	12.9±0.3	12.6±0.2	12.9	**
ICCV 08302	31.9±3.6	22.6±1.8	32.1±4.1	43.5±1.9	32.5	12.4±0.3	13.5±0.3	12.9±0.3	12.3±0.2	12.7	**
ICCV 92311	37.4±3.6	27.5±1.8	42.4±4.1	53.2±1.9	40.1	13.4±0.3	13.7±0.3	13.1±0.3	13.4±0.2	13.4	**
ICC 15802	63.3±3.6	54.5±1.8	56.8±4.1	54.4±1.9	57.3	13.7±0.3	13.5±0.3	13.2±0.3	13.3±0.2	13.4	**
ICCV 07308	29.6±3.6	23.2±1.8	32.0±4.7	42.8±1.9	31.9	12.6±0.3	13.1±0.3	12.5±0.4	12.4±0.2	12.6	**
ICC 10885©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
ICC 13357©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
ICC 16654©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
ICC 7315©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
ICCV 03309©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
ICCV 06304©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
ICCV 08310©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
ICCV 07304©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
K004©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
K012©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
ICCV 08313©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
K034©	46.6±12.1	37.7±12.1	47.6±12.2	48.3±12.1	45.1	13.4±0.6	13.6±0.6	13.0±0.6	13.4±0.6	13.3	**
IG 72109	60.5±3.6	57.7±1.8	61.3±4.1	55.7±1.9	58.8	14.6±0.3	14.0±0.3	13.3±0.3	14.3±0.2	14.0	**
ICCV 08303	33.0±3.6	22.9±1.8	34.6±4.1	37.6±1.9	32.0	13.1±0.3	13.6±0.3	13.3±0.3	12.6±0.2	13.1	**
K041	38.4±3.6	29.2±1.8	36.9±4.1	47.6±1.9	38.0	13.0±0.3	13.2±0.3	13.1±0.3	12.8±0.2	13.0	**

Continue Table 4.9

K022	65.3+4.3	55.2±1.8	58.0±4.1	50.7±1.9	57.3	13.7±0.3	14.0±0.3	13.3±0.3	13.3±0.2	13.6	**
K017	44.0±3.6	31.5±1.8	49.2±4.1	40.1±1.9	41.2	13.3±0.3	14.0±0.3	12.3±0.3	13.3±0.2	13.2	**
K025	32.1±4.3	24.8±1.8	42.5±4.1	50.9±1.9	37.6	13.9±0.3	14.0±0.3	13.5±0.3	13.6±0.2	13.7	**
ICCV 08307	35.3±3.6	25.0±1.8	38.1±4.1	46.5±1.9	36.2	13.3±0.3	13.8±0.3	13.0±0.3	13.9±0.2	13.5	**
ICCV 92318 (Check)	32.0±3.6	34.6±1.8	43.3±4.1	50.8±1.9	40.2	12.5±0.3	12.6±0.3	12.3±0.3	12.7±0.2	12.5	**
ICC 13283	72.3±4.3	59.0±1.8	75.1±4.1	52.7±1.9	64.8	13.5±0.3	13.2±0.3	12.6±0.3	13.3±0.2	13.1	**
K038	36.5±3.6	27.4±1.8	43.6±4.1	51.1±1.9	39.6	13.4±0.3	13.9±0.3	13.0±0.3	14.4±0.2	13.7	**
Mean	46.6	37.7	47.6	48.3	45.1	13.4	13.6	13.0	13.4	13.3	
Minimum	72.3	59.0	75.1	58.0	64.8	12.4	12.3	12.3	12.3	12.4	
Maximum	29.6	22.6	32.0	37.6	31.9	14.6	14.5	14.1	15.3	14.4	

** -significant at 1 %, * - significant at 5 % and NS – non –significant at 5 % level of significant, ©- Genotypes were analysed using missing block and hence they have the same values for all traits, Pr- Probability value

Plant Canopy Width

Genotypes and genotype by environment interactions showed highly significant ($p < 0.0001$) differences for plant canopy width (Table 4.10). Most genotypes recorded larger plant canopy width during long rains compared to short rains at both sites, except twelve genotypes that recorded larger plant canopy width in short rain season at Kabete. Likewise most genotypes except ICC 13461 recorded larger plant canopy width in long rain season at Juja compared to long rain season Kabete. The largest (ICC 2482, ICC 13461, ICC 13764 and ICC 13283) and the smallest (K038, ICCV 07306, ICCV 08303 and ICCV 92318) genotypes for plant canopy width at Juja also recorded the largest and the smallest values in Kabete. The ranking of the genotypes for plant canopy width varied across environments. Eleven and thirty five genotypes surpassed the check varieties ICCV 00305 and ICCV 92318 for plant canopy width respectively.

Based on overall means, the genotypes showed significant differences with respect to plant canopy width. Five genotypes could be categorized as small (< 60 cm), 11 genotypes as medium (60.0 – 70.0 cm) and 13 genotypes had large (> 70 cm) plant canopy width. The largest plant canopy width was recorded for genotype ICC 13461 (90.6 cm) followed by ICC 2482 (87.4 cm), ICC 13764 (86.9 cm) and IG 71055 (80.3 cm). While genotype K038 (54.2 cm) followed by ICCV 07306 (55.2 cm), ICCV 08303 (56.0 cm) and ICCV 92318 (57.4 cm) recorded the smallest plant canopy width. The check varieties ICCV 00305 (71.1 cm) and ICCV 92318 (57.4 cm) were classified as having large and small plant canopy width respectively. Based on environment wise means, the largest plant canopy width among genotypes was recorded in the long rain season Juja (81.1 cm) followed by short rain season Juja (74.4 cm), long rain season Kabete (62.9 cm) and short rain season Kabete (61.2 cm) with a grand mean of 69.9 cm.

Pod Length

There were highly significant ($p < 0.0001$) variation among studied genotypes and genotype by environment interactions for pod length (Table 4.10). The evaluated genotypes recorded longer pod length during short rains compared to long rains at both sites. In addition, all genotypes recorded longer pod length at Juja as compared to Kabete. The longest (ICCV 03404, K038 and K025) and the shortest (ICC 13764, ICC 13461, ICC 2482 and ICC 13283) genotypes for pod length at Juja also recorded the longest and the shortest at Kabete.

The ranking of genotypes for pod length differed across environments except ICC 13764 which consistently recorded medium pod length. Twenty nine and nine genotypes surpassed the check varieties ICCV 00305 and ICCV 92318 for pod length individually.

On the basis of overall means, the genotypes showed a wide range of variations for pod length. Based on the descriptors for chickpea, the genotypes classified into medium and long pod length. Four genotypes were classified as medium (15.0 - 20 mm) and 35 genotypes had long pod length (> 20 mm). Genotypes ICCV 03404 (30.5 mm) and K038 (28.1 mm) followed by ICCV 08302 (27.7 mm), K017 (27.2 mm) and K025 (27.1 mm) recorded the longest pod length. While genotypes ICC 13764 (17.0 mm), ICC 13461 (18.5 mm), ICC 15802 (19.5 mm) and ICCV 00402 (19.9 mm) were the shortest. The check varieties ICCV 00305 (23.8 mm) and ICCV 92318 (25.3 mm) were classified as long pod length. With respect to environment wise means, the longest pod length among genotypes was recorded in short rain season Juja (30.3 mm) followed by short rain season Kabete (26.0 mm), long rain season Juja (21.9 mm) and long rain season Kabete (18.4 mm) with a grand mean of 24.1 mm.

Table 4.10:Performance of *Kabuli* Genotypes for -Plant Canopy Width and Pod Length at Juja and Kabete

	Plant Canopy Width in centimeters					Pod Length in millimeters					
	Long Rain Juja	Short Rain Juja	Long Rain Kabete	Short Rain Kabete	Overall	Long Rain Juja	Short Rain Juja	Long Rain Kabete	Short Rain Kabete	Overall	
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Pr.
ICCV 05315	72.8±5.7	86.0±3.7	53.0±4.5	58.5±1.8	67.6	24.6±1.4	34.0±1.2	19.6±1.2	27.1±1.2	26.3	**
ICC 13461	100.4±5.7	80.4±3.7	105.8±4.5	75.9±1.8	90.6	16.1±1.4	23.9±1.2	12.7±1.2	21.3±1.2	18.5	**
ICCV 07313	82.3±5.7	79.5±3.7	54.5±4.5	55.9±1.8	68.0	22.6±1.4	32.1±1.2	19.3±1.2	28.3±1.2	25.6	**
ICC 13764	102.7±6.7	90.0±3.7	79.1±4.5	75.9±1.8	86.9	13.9±1.4	22.2±1.2	12.0±1.2	19.8±1.2	17.0	**
ICCV 00302	80.0±5.7	64.6±3.7	76.4±4.5	56.7±1.8	69.4	21.9±1.4	29.5±1.2	18.7±1.2	28.2±1.2	24.6	**
ICC 2482	108.8±6.7	91.8±3.7	81.0±5.4	68.0±1.8	87.4	18.3±1.4	27.1±1.2	14.0±1.4	26.7±1.2	21.5	**
ICCV 03404	93.6±5.7	71.0±3.7	71.9±4.5	66.9±1.8	75.8	30.2±1.4	34.8±1.2	26.4±1.4	30.6±1.2	30.5	**
ICCV 00402	77.71±6.7	71.8±3.7	63.1±4.5	49.5±1.8	65.5	16.5±1.4	24.3±1.2	15.7±1.2	23.3±1.2	19.9	**
ICCV 07306	69.0±5.6	63.9±3.7	42.2±4.5	45.6±1.8	55.2	22.0±1.4	30.8±1.2	19.5±1.2	26.6±1.2	24.7	**
ICCV 00305 (Check)	92.1±5.7	65.3±3.7	74.0±4.5	52.8±1.8	71.1	21.8±1.4	30.1±1.2	18.1±1.2	25.3±1.2	23.8	**
ICCV 05312	69.0±5.7	76.1±3.7	42.3±4.5	57.2±1.8	61.1	20.3±1.4	33.4±1.2	17.2±1.2	26.8±1.2	24.4	**
IG 71055	71.9±6.7	89.9±3.7	88.0±4.5	71.3±1.8	80.2	19.8±1.4	29.5±1.2	17.3±1.2	25.3±12.	22.9	**
ICCV 08302	77.0±5.7	69.3±3.7	63.9±4.5	70.4±1.8	70.1	26.0±1.4	32.8±1.2	25.0±1.2	27.0±1.2	27.7	**
ICCV 92311	80.6±6.7	67.7±3.7	85.8±4.5	51.4±1.8	71.4	22.9±1.4	31.7±1.2	19.3±1.2	27.1±1.2	25.2	**
ICC 15802	80.3±6.7	74.4±3.7	79.5±5.4	67.7±1.8	75.5	16.8±1.4	23.7±1.2	14.9±1.2	22.7±1.2	19.5	**
ICCV 07308	72.6±5.7	72.4±3.7	44.9±5.4	55.8±1.8	61.4	22.7±1.4	32.6±1.2	18.6±1.4	26.4±1.2	25.1	**
ICC 10885©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
ICC 13357©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
ICC 16654©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
ICC 7315©	81.1±13.6	74.43±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
ICCV 03309©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
ICCV 06304©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
ICCV 08310©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
ICCV 07304©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
K004©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
K012©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
ICCV 08313©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
K034©	81.1±13.6	74.4±13.6	62.9±13.6	61.2±13.6	69.9	21.9±3.7	30.2±3.7	18.4±3.7	26.0±3.7	24.1	**
IG 72109	91.0±5.7	77.7±3.7	42.1±5.4	90.3±1.8	75.3	18.7±1.4	28.2±1.2	14.7±1.2	24.8±1.2	21.6	**
ICCV 08303	73.5±5.7	64.1±3.7	45.0±4.5	41.4±1.8	56.0	23.5±1.4	27.3±1.2	16.1±1.2	25.0±1.2	23.0	**

Continue Table 4.10

ICCV 95311	79.6±5.7	79.7±3.7	65.9±4.5	62.8±1.8	72.0	22.2±1.4	31.9±1.2	19.7±1.2	25.3±1.2	24.8	**
K041	79.4±5.7	80.9±3.7	57.4±4.5	57.2±1.8	68.7	22.7±1.4	33.8±1.2	19.7±1.2	27.7±1.2	26.0	**
K022	75.4±6.7	59.8±3.7	48.8±4.5	55.2±1.8	59.8	21.3±1.6	31.2±1.2	18.6±1.2	27.2±1.2	24.5	**
K017	76.1±5.7	71.6±3.7	56.1±5.4	54.3±1.8	64.5	25.3±1.4	35.5±1.2	20.5±1.2	27.5±1.2	27.2	**
K025	81.5±6.7	76.1±3.7	66.8±4.5	75.6±1.8	75.0	25.9±1.6	32.7±1.2	20.6±1.2	29.1±1.2	27.1	**
ICCV 08307	67.0±5.7	80.8±3.7	56.1±4.5	69.7±1.8	68.4	24.7±1.4	33.0±1.2	21.2±1.2	27.3±1.2	26.5	**
ICCV 92318 (Check)	73.5±5.7	62.6±3.7	43.0±4.5	50.6±1.8	57.4	24.0±1.4	31.2±1.2	20.4±1.2	25.5±1.2	25.2	**
ICC 13283	93.6±6.7	85.4±3.7	70.9±5.4	63.1±1.8	78.2	18.3±1.6	24.1±1.2	15.4±1.2	22.4±1.2	20.0	**
K038	67.6±5.7	57.0±3.7	39.8±4.5	52.4±1.8	54.2	27.6±1.4	33.7±1.2	22.7±1.2	28.3±1.2	28.1	**
Mean	81.1	74.4	62.9	61.2	69.9	21.9	30.2	18.4	26.0	24.1	
Minimum	67.0	57.0	39.8	41.4	54.2	13.9	22.2	12.1	19.7	17.0	
Maximum	108.8	91.8	105.8	90.3	90.6	30.2	35.5	26.4	30.5	30.5	

Plant Height

There were highly significant ($p < 0.0001$) differences among the genotypes and genotype by environment interactions for plant height (Table 4.11). Genotypes recorded taller plant height in Juja compared to Kabete. The studied genotypes recorded taller plant height during long rains compared to short rain season at Juja. While at Kabete some genotypes recorded taller plant height during short rain season and vice versa. The tallest (IG 72019, IG 71055 and ICC 13461) and the shortest (ICCV 07306, ICCV 92318 and K022) genotypes for plant height at Juja also recorded the tallest and the shortest plant height at Kabete. The ranking of genotypes for plant height varied across environments. Genotypes showed inconsistent performance for plant eight across environments. Twenty six and thirty six genotypes were taller than the check varieties ICCV 00305 and ICCV 92318 respectively.

Based on overall means, the genotypes differed with respect to plant height. Three genotypes could be classified as short (< 40 cm), 30 genotypes as medium (40.1 – 50.0 cm) and 6 genotypes had tall plant height (> 50.0 cm). Genotypes IG 71055 (58.9 cm), IG 72109 (54.4 cm) ICC 13461 (53.8 cm), ICCV 03404 (53.0 cm) and K025 (52.0 cm) recorded the tallest plant height. While genotype ICCV 07306 (37.2 cm) followed by K022 (39.8 cm), ICCV 92318 (39.9 cm) and K017 (40.3 cm) were the shortest. The check varieties ICCV 00305 (45.6 cm) and ICCV 92318 (39.9 cm) were classified as medium and short respectively. Based on environment wise means, the tallest plant height was recorded in long rain season Juja (56.3 cm) followed by short rain season Juja (50.0 cm), short rain season Kabete (39.9 cm) and long rain season Kabete (39.1 cm) with a grand mean of 46.3 cm.

Number of Primary Branches

Genotypes and genotype by environment interactions showed highly significant ($p < 0.003$) variation for number of primary branches plant $^{-1}$ (Table 4.11). Evaluated genotypes recorded higher number of primary branches plant $^{-1}$ at Juja compared to Kabete. Most genotypes except ICC 1328, ICC 15802, ICC 2482, ICCV 03404, ICCV 05315, ICCV 08302 and IG 71055 recorded higher number of primary branches plant $^{-1}$ in long rain season compared to short rain season at Juja.

While at Kabete all genotypes except ICC 13764, ICCV 08303, ICCV 00302, ICCV 00305, ICCV 92311 and ICCV 95311 recorded higher number of primary branches plant $^{-1}$ in short rains compared to long rain season. The ranking of genotypes for number of primary branches plant $^{-1}$ varied across environment. Twenty five and thirty four genotypes surpassed the check varieties ICCV 00305 and ICCV 92318 for number primary branches plant $^{-1}$ individually.

On the basis of overall means, the results indicated significant differences with respect to number of primary branches plant $^{-1}$ and 13 genotypes were categorized as low (< 10), 21 genotypes as moderate (10.0 – 13.0) and 5 genotypes had high (> 13) number of primary branches plant $^{-1}$. The highest number of primary branches plant $^{-1}$ was recorded for genotypes ICC 13283 (19.0), ICC 13461 (18.0), IG 72109 (18.0), IG 71055 (17.1) and ICC 15802 (14.2). While genotypes K038 (7.2), ICCV 07308 (8.2), ICCV 92318 (8.5) and ICCV 08307 (8.5) recorded the lowest number of primary branches plant $^{-1}$. The check varieties ICCV 00305 (10.0) and ICCV 92318 (8.5) were classified as moderate and low respectively for primary branches plant $^{-1}$. With respect to environment wise means, the highest number of primary branches plant $^{-1}$ was recorded in long rain season Juja (14.5) followed by short rain season Juja (12.8), short rain Kabete (9.7) and long rain season Kabete (7.7) with a grand mean of 11.2.

Table 4.11: Variation among *Kabuli* Genotypes for Plant Height and Number of Primary Branches Plant $^{-1}$ at Juja and Kabete

Genotypes	Plant Height in centimeters					Number of Primary Branches Plant $^{-1}$					
	Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Pr.
ICCV 05315	53.4±3.6	49.4±2.1	35.6±3.1	39.7±1.1	44.5	13.8±1.5	15.0±1.3	5.8±1.1	5.8±0.6	10.9	**
ICC 13461	64.6±3.7	52.4±2.1	51.0±3.1	47.4±1.1	53.8	21.0±1.5	17.9±1.3	13.5±1.1	13.5±0.6	18.0	**
ICCV 07313	53.4±3.6	46.9±2.1	37.5±3.1	38.4±1.1	44.1	12.7±1.5	10.6±1.3	7.0±1.1	7.0±0.6	9.7	**
ICC 13764	59.8±3.7	55.9±2.1	41.9±3.1	39.0±1.1	49.2	15.8±1.5	14.3±1.3	11.2±1.1	11.2±0.6	12.8	**
ICCV 00302	60.8±3.6	48.24±2.1	42.0±3.1	34.6±1.1	46.4	12.6±1.5	11.6±1.3	7.9±1.1	7.9±0.6	9.9	**
ICC 2482	61.6±3.6	48.9±2.1	46.0±3.5	42.9±1.1	49.8	15.1±1.5	18.8±1.3	7.8±1.3	7.8±0.5	12.4	**
ICCV 03404	63.1±3.6	57.1±2.1	50.8±3.5	41.2±1.1	53.0	14.1±1.5	15.4±1.3	5.2±1.3	5.2±0.6	10.8	**
ICCV 00402	53.3±3.6	49.0±2.1	32.6±3.1	39.8±1.1	43.7	15.0±1.7	12.1±1.3	6.5±1.1	6.5±0.6	11.1	**
ICCV 07306	50.1±3.6	42.1±2.1	24.2±3.1	32.5±1.1	37.2	12.6±1.5	9.9±1.3	5.0±1.1	5.0±0.6	9.3	**
ICCV 00305(Check)	59.3±3.6	47.0±2.1	41.9±3.1	34.3±1.1	45.6	16.2±1.5	9.4±1.3	8.4±1.1	8.4±0.6	10.0	**
ICCV 05312	51.0±3.6	43.2±2.1	36.6±3.1	35.4±1.1	41.6	13.4±1.5	9.7±1.3	5.4±1.3	5.4±0.6	9.3	**
IG 71055	63.5±3.6	64.5±2.1	51.8+3.1	56.0±1.1	58.9	15.3±1.7	18.2±1.3	15.7±1.1	15.7±0.6	17.1	**
ICCV 08302	56.0±3.6	52.1±2.1	42.5±3.1	35.7±1.1	46.6	12.7±1.5	14.1±1.3	6.9±1.1	6.9±0.6	10.5	**
ICCV 92311	54.3±3.6	48.3±2.1	39.9±3.1	33.0±1.1	43.9	15.3±1.5	9.4±1.3	9.9±1.1	9.9±0.6	10.4	**
ICC 15802	50.4±3.6	48.4±2.1	42.6±3.5	37.1±1.1	44.6	15.6±1.7	18.5±1.3	10.9±1.1	10.9±0.6	14.2	**
ICCV 07308	54.4±3.6	52.0±2.1	34.4±3.5	39.6±1.1	45.1	12.8±1.5	8.6±1.3	5.6±1.3	5.6±0.6	8.2	**
ICC 10885©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
ICC 13357©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
ICC 16654©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
ICC 7315©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
ICCV 03309©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
ICCV 06304©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
ICCV 08310©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
ICCV 07304©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
K004©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
K012©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
ICCV 08313©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
K034©	56.3±6.7	50.0±6.6	39.1±6.6	39.9±6.6	46.3	14.5±4.0	12.8±4.0	7.7±4.0	7.7±4.0	11.2	**
IG 72109	67.3±3.6	58.9±2.1	43.2±3.1	48.1±1.1	54.4	26.7±1.5	21.7±1.3	10.7±1.1	10.7±0.6	18.0	**
ICCV 08303	54.0±3.6	48.5±2.1	28.8±3.1	35.1±1.1	41.6	11.8±1.5	9.7±1.3	6.4±1.1	6.4±0.6	8.5	**
ICCV 95311	56.0±3.6	52.1±2.1	37.4±3.1	38.1±1.1	45.9	11.7±1.5	11.1±1.3	8.6±1.1	8.6±0.6	9.7	**

Continue Table 4. 11

K041	53.8±3.6	48.4±2.1	42.5±3.1	36.9±1.1	45.4	16.3±1.5	12.1±1.3	7.0±1.1	7.0±0.6	11.1	**
K022	51.1±4.0	41.4±2.1	31.9±3.1	34.7±1.1	39.8	13.3±1.7	9.4±1.3	6.2±1.1	6.2±0.6	8.8	**
K017	52.3±3.6	46.3±2.1	24.3±3.5	38.2±1.1	40.3	10.4±1.5	10.1±1.3	6.0±1.3	5.6±0.6	8.6	**
K025	60.9±4.0	52.2±2.1	44.4±3.1	50.5±1.1	52.0	13.7±1.7	11.4±1.3	6.3±1.3	6.3±0.6	10.0	**
ICCV 08307	52.3±3.6	49.6±2.1	40.0±3.1	44.7±1.1	46.6	11.7±1.5	9.7±1.3	5.0±1.1	5.0±0.6	8.5	**
ICCV 92318 (Check)	50.8±3.6	43.6±2.1	31.4±3.1	33.8±1.1	39.9	13.3±1.5	8.2±1.3	4.7±1.1	4.7±0.6	8.4	**
ICC 13283	60.7±4.0	52.0±2.1	47.5±3.1	43.1±1.0	50.8	18.9±1.7	22.2±1.3	11.8±1.3	11.8±0.5	19.0	**
K038	52.9±3.6	51.6±2.1	33.3±3.1	46.5±1.1	46.1	10.3±1.5	7.6±1.3	3.8±1.1	3.8±0.6	7.2	**
Mean	56.3	50.0	39.1	39.9	46.3	14.5	12.8	7.7	9.7	11.2	
Minimum	50.1	41.4	24.2	32.5	37.2	10.3	7.6	3.8	5.6	7.2	
Maximum	67.3	64.5	51.8	56.0	58.9	26.7	22.2	15.7	22.9	19.0	

Number of Secondary Branches

There were highly significant ($p < 0.004$) differences among genotypes and genotype by environment interactions for number of secondary branches plant $^{-1}$ (Table 4.12).Genotypes recorded higher number of secondary branches plant $^{-1}$ during both seasons at Juja compared to Kabete except K038, ICCV 92318, ICCV 05312, ICCV 03404, ICCV 00402 and ICC 13461 which recorded high values in short rain season at Kabete. Genotypes ranking for number of secondary branches plant $^{-1}$varied across environments. Twenty three and thirty three genotypes exceeded the check varieties ICCV 00305 and ICCV 92318 for number of secondary branches plant $^{-1}$ respectively.

Based on overall means, the genotypes varied with respect to number of secondary branches plant $^{-1}$. Fifteen genotypes had low (< 15), 18 genotypes had moderate (15 – 20.0) and 6 genotypes had high (> 20) number of secondary branches plant $^{-1}$. The highest number of secondary branches plant $^{-1}$ was recorded for genotypes ICC 13461 (34.5), IG 71055 (31.6), IG 72109 (25.8) and ICC 13283 (25.5). Genotype K038 (8.9) followed by K017 (10.1), ICCV 05312 (10.2) and ICCV 08302 (10.4) recorded the lowest. The check varieties ICCV 00305 (15.3) and ICCV 92318 (12.1) were classified as moderate and low respectively for number of secondary branches plant $^{-1}$. Based on the environment wise means, the highest number of secondary branches plant $^{-1}$ was recorded in the long rain season Juja (24.0) followed by short rain season Juja (19.6), short rain season Kabete (13.8) and long rain season Kabete (8.5) with a grand mean of 16.5.

Days to 75 % Maturity

Genotypes and genotype by environment interactions showed highly significant ($p < 0.0001$) variation for days to 75 % physiological maturity (Table 4.12). Evaluated genotypes took longer time to mature in the long rains compared to short rain season at both sites. Genotypes took shorter time to maturity at Juja compared to Kabete in both seasons. The ranking of genotypes for days to maturity differed across environments. Twenty one and six genotypes matured earlier than the check varieties ICCV 00305 and ICCV 92318 respectively.

Based on overall means, the results indicated genotypes varied in their response to maturity. Ten genotypes were classified as early (< 112 days), 20 genotypes as moderate (112.0 – 115.0 days) and 9 genotypes were late (> 115.0 days) maturing.

The earliest maturing genotypes were ICCV 08303 (109 days) followed by ICCV 07308 (110 days), K041 (110 days) and ICCV 05312 (111 days). While genotype IG 71055 (123 days) followed by ICC 13283 (121 days), IG 72109 (120 days), ICC 13461 (120 days) and ICCV 00302 (118 days) were the latest in maturity. The check varieties ICCV 00305 (114 days) and ICCV 92318 (113 days) were classified as moderate in maturity. Based on environment wise means, the earliest maturity was recorded in short rain season at Juja (92 days) followed by short rain season at Kabete (105 days), long rain season at Juja (122 days) and long rain season Kabete (139 days) with a grand mean of 114 days.

Table 4.12: Variation among *Kabuli* Genotypes for Secondary Branches Plant $^{-1}$ and Days to Maturity at Juja and Kabete

	Number of Secondary Branches Plant $^{-1}$					Days to 75 % Maturity					
Genotypes	Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Pr.
ICCV 05315	29.4±3.4	26.0±0.7	26.0±1.0	17.4±0.8	19.5	118.1±2.2	92.1±1.2	138.9±2.4	98.2±1.8	111.8	**
ICC 13461	37.6±2.9	31.7±0.7	31.7±1.0	35.2±0.8	34.5	127.1±2.2	97.2±1.2	139.2±2.4	115.0±1.8	119.6	**
ICCV 07313	18.4±2.9	17.3±0.7	17.3±1.0	17.2±0.8	14.9	123.3±2.2	86.4±1.2	136.2±2.4	103.3±1.8	112.3	**
ICC 13764	29.0±2.9	23.9±0.7	23.9±1.0	15.3±0.8	21.7	125.7±2.2	101.0±1.2	140.0±2.4	103.9±1.8	117.6	**
ICCV 00302	25.8±2.9	18.5±0.7	18.5±1.0	10.5±0.8	15.6	127.5±2.2	101.6±1.2	138.2±2.4	105.8±1.8	118.3	**
ICC 2482	22.3±3.4	31.6±0.7	31.6±1.2	8.2±0.8	17.4	124.5±2.2	93.7±1.2	140.2±2.7	108.5±1.8	116.7	**
ICCV 03404	23.3±2.9	12.7±0.7	12.7±1.2	15.9±0.8	14.4	119.4±2.2	91.7±1.2	137.7±2.4	109.4±1.8	114.5	**
ICCV 00402	25.4±3.4	10.8±0.7	10.8±1.0	18.3±0.8	15.4	120.9±2.2	89.3±1.2	143.7±2.4	106.1±1.8	115.0	**
ICCV 07306	22.1±2.9	17.8±0.7	17.8±1.0	9.3±0.8	13.3	122.4±2.2	92.0±1.2	142.5±2.4	104.9±1.8	115.4	**
ICCV 00305(Check)	29.4±2.9	14.4±0.7	14.4±1.0	9.6±0.8	15.3	125.2±2.2	91.1±1.2	139.6±2.4	101.8±1.8	114.4	**
ICCV 05312	15.9±2.9	10.9±0.7	10.9±1.0	12.0±0.8	10.2	118.4±2.2	85.0±1.2	139.7±2.4	98.8±1.8	110.5	**
IG 71055	29.3±2.9	38.6±0.7	38.6±1.0	36.±0.8	31.6	127.3±2.2	98.1±1.2	149.2±2.4	119.0±1.8	123.4	**
ICCV 08302	14.9±3.4	15.4±0.7	15.4±1.0	8.8±0.8	10.4	119.5±2.2	88.7±1.2	139.6±2.4	96.0±1.8	110.9	**
ICCV 92311	15.8±2.9	13.5±0.7	13.5±1.0	11.1±0.8	12.2	121.2±2.2	88.3+1.2	138.7±2.4	105.6±1.8	113.4	**
ICC 15802	24.5±3.4	33.1±0.7	33.1±1.0	13.6±0.8	22.1	119.5±2.2	91.9±1.2	141.3±2.4	103.3±1.8	114.0	**
ICCV 07308	20.6±2.9	18.0±0.7	18.0±1.2	5.5±0.8	12.0	120.2±2.2	89.2±1.2	134.4±2.7	96.3±1.8	110.0	**
ICC 10885©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
ICC 13357©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
ICC 16654©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
ICC 7315©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
ICCV 03309©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
ICCV 06304©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
ICCV 08310©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
ICCV 07304©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
K004©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
K012©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
ICCV 08313©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±5.2	114.3	**
K034©	24.0±8.0	19.6±8.0	19.6±8.0	13.8±8.0	16.5	121.6±5.2	91.6±5.2	139.4±5.3	104.7±1.8	114.3	**
IG 72109	42.3±2.9	24.6±0.7	24.6±1.0	17.0±0.8	25.8	124.2±2.2	97.5±1.2	141.4±2.4	118.0±1.8	120.3	**
ICCV 08303	19.2±2.9	20.8±0.7	20.8±1.0	7.2±0.8	12.7	118.7±2.2	87.0±1.2	135.5±2.4	93.8±1.8	108.7	**
ICCV 95311	27.9±2.9	19.9±0.7	19.9±1.0	12.1±0.8	17.3	124.7+2.2	90.0±1.2	140.3±2.4	110.3±1.8	116.3	**

Continue Table 4.12

K041	22.4±2.9	13.8±0.7	13.8±1.0	11.7±0.8	13.1	117.0±2.2	89.9±1.2	135.7±2.4	99.0±1.8	110.4	**
K022	24.0±3.4	10.7±0.7	10.7±1.0	9.0±0.8	12.3	123.3±2.6	94.1±1.2	139.4±2.4	100.5±1.8	114.3	**
K017	12.7±3.4	15.4±0.7	15.4±1.0	9.0±0.8	10.1	119.8±2.2	87.8±1.2	136.9±2.4	101.6±1.8	111.5	**
K025	21.5±3.4	16.3±0.7	16.3±1.0	9.3±0.8	12.5	114.9±2.6	86.9±1.2	140.8±2.4	103.1±1.8	111.4	**
ICCV 08307	16.9±3.4	23.7±0.7	23.7±1.0	12.3±0.8	13.9	116.8±2.2	86.6±1.2	137.7±2.4	101.2±1.8	110.6	**
ICCV 92318 (Check)	23.6±2.9	8.3±0.7	8.3±1.0	11.2±0.8	12.1	117.8±2.2	92.8±1.2	137.7±2.4	103.4±1.8	112.9	**
ICC 13283	39.5±3.4	32.7±0.7	32.7±1.2	17.2±0.8	25.4	126.1±2.6	98.2±1.2	142.3±2.4	119.0±1.8	121.4	**
K038	14.1±2.9	8.1±0.7	8.1±1.0	11.6±0.8	8.9	120.9±2.2	85.4±1.2	137.9±2.4	100.5±1.8	111.2	**
Mean	24.0	19.6	8.5	13.8	16.5	121.6	91.6	139.4	104.7	114.3	
Minimum	12.7	8.1	1.8	5.4	8.9	114.9	85.0	134.4	93.8	108.7	
Maximum	42.3	38.6	33.6	36.6	34.5	127.5	101.6	149.2	119.0	123.4	

Pod Filling Period

There were highly significant ($p < 0.0001$) differences among genotypes and genotype by environment interactions for pod filling period (Table 4.13). The studied genotypes took a shorter pod filling period during short rains compared to long rains at both sites. The genotypes took longer pod filling period at Kabete compared to Juja in both seasons. Genotypes with the earliest (K022, ICC 13283 and ICC 15802) and the latest (ICCV 07308, ICCV 03404, ICCV 08302 and ICCV 08303) for pod filling period at Juja took shorter time and longer time at Kabete. The ranking of genotypes for pod filling period varied across environments which indicated a crossover type of genotype by environment interactions. Eight and thirty one genotypes took shorter than the check varieties ICCV 00305 and ICCV 92318 for pod filling period respectively.

Based on overall means, there were significant differences with respect to pod filling period. Eight genotypes could be classified as early (< 65 days), 15 genotypes as moderate (65 – 70 days) and 16 genotypes were late (> 70 days) for pod filling period. Genotypes ICC 13283 (56 days) followed by ICC 15802 (57 days), K022 (57 days) and ICC 13461 (58 days) were the earliest in pod filling. While genotype ICCV 03404 (79 days) followed by ICCV 08302 (78 days), ICCV 07306 (78 days), ICCV 07308 (78 days) and ICCV (77 days) were the latest in pod filling period. The check varieties ICCV 00305 (67 days) and ICCV 92318 (75 days) were categorized as moderate and late respectively. With respect to environment wise means, the earliest pod filling period was recorded in the short rain season Juja (54 days) followed by short rain season Kabete (57 days), long rain season Juja (75 days) and long rain season Kabete (92 days) with a grand mean of 70 days.

4.2.2. Yield and Yield Related Traits Evaluation

Number of Pods Plant $^{-1}$

There were highly significant ($p < 0.001$) differences among genotypes and genotype by environment interactions for number of pods plant $^{--1}$ (Table 4.13). Twenty eight genotypes recorded higher number of pods plant $^{-1}$ during long rain compared to short rain season at Juja. While at Kabete, most genotypes except ICC 2482, IG 72109 and K017 recorded higher number of pods plant $^{-1}$ during the long rain season. All genotypes except ICC 13764, ICC 15802, ICC 2482; ICCV 00302, ICCV 08302 and ICCV 92311 recorded higher number of pods plant $^{-1}$ during long rain season at Juja compared to long rain season at Kabete. Genotypes recorded lower number of pods plant $^{-1}$ during short rain season at Kabete except ICC 2482 and ICCV 00402. Genotypes ranking for number of pods plant $^{-1}$varied across environments. The genotypes which performed better in Juja were not necessarily performed better at Kabete. Seven and thirty seven genotypes exceeded the check varieties ICCV 00305 and ICCV 92318 for number of pods plant $^{-1}$ respectively, which indicated the existence of variation.

On the basis of overall means, the genotypes showed significant differences with respect to number of pods plant $^{-1}$. Eight genotypes were classified as low (< 60), 6 genotypes as moderate (60.0 – 70.0) and 25 genotypes had high (> 70) number of pods plant $^{-1}$. Genotype IG 71055 (139.1) followed by ICC 13461 (133.0), ICC 13764 (107.7), ICCV 00302 (100.6) and IG 72109 (89.1) recorded the highest number of pods plant $^{-1}$. Genotypes K038 (37.9), ICCV 92318 (44.2), ICCV 07308 (49.7), ICCV 05312 (51.6) and ICCV 08302 (51.9) recorded the lowest number of pod plant $^{-1}$. The check varieties ICCV 00305 (84.1) and ICCV 92318 (44.2) were classified as genotypes having high and low for number of pods plant $^{-1}$ respectively. Based on environment-wise means, the highest number of pods plant $^{-1}$ was recorded in the long rain season Juja (91.5) followed by short rain season Juja (80.6), long rain season Kabete (75.4) and short rain season Kabete (46.8) with a grand mean of 73.6.

Table 4.13: Performance of *Kabuli* Genotypes for Pod Filling Period and Number of Pods Plant $^{-1}$ at Juja and Kabete

	Pod Filling Period					Number of Pods Plant $^{-1}$					
	Long Rain Juja	Short Rain Juja	Long Rain Kabete	Short Rain Kabete	Overall	Long Rain Juja	Short Rain Juja	Long Rain Kabete	Short Rain Kabete	Overall	
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Pr.
ICCV 05315	79.9±4.0	61.3±2.0	94.4±4.3	49.3±2.6	71.2	74.6±9.4	107.4±4.1	58.4±7.8	52.0±2.4	73.1	**
ICC 13461	58.0±4.0	39.7±2.0	73.1±4.3	59.1±2.6	57.5	169.1±9.4	135.0±4.1	149.3±7.8	78.4±2.4	133.0	**
ICCV 07313	85.1±4.0	58.0±2.0	98.3±4.3	63.7±2.6	76.3	147.0±11.3	89.0±4.1	67.8±7.8	36.2±2.4	85.0	**
ICC 13764	67.5±4.0	51.0±2.0	85.5±4.3	53.3±2.6	64.3	107.3±9.4	152.5±4.1	116.8±7.8	54.0±2.4	107.7	**
ICCV 00302	71.3±4.0	59.3±2.0	91.2±4.3	57.9±2.6	69.9	77.4±9.4	146.5±4.1	118.5±7.8	60.1±2.4	100.6	**
ICC 2482	68.4±4.0	36.8±2.0	83.9±5.1	57.0±2.6	61.5	68.9±11.3	42.9±4.1	86.4±9.5	89.6±2.4	71.9	**
ICCV 03404	85.3±4.0	66.3±2.0	99.2±4.3	64.5±2.6	78.8	95.3±9.4	66.1±4.1	42.9±7.8	38.3±2.4	60.7	**
ICCV 00402	75.4±4.0	55.6±2.0	96.7±4.3	53.4±2.6	70.3	69.0±11.3	131.3±4.1	69.6±7.8	73.2±2.4	85.8	**
ICCV 07306	86.9±4.0	61.9±2.0	97.1±4.3	65.9±2.6	78.0	79.8±9.4	102.7±4.1	53.2±7.8	32.2±2.4	67.0	**
ICCV 00305 (Check)	73.6±4.0	51.4±2.0	92.1±4.3	50.2±2.6	66.8	136.2±9.4	61.0±4.1	89.6±7.8	49.6±2.4	84.1	**
ICCV 05312	85.6±4.0	59.5±2.0	98.4±4.3	54.6±2.6	74.5	59.3±9.4	55.6±4.1	49.4±7.8	42.1±2.4	51.6	**
IG 71055	61.0±4.0	40.2±2.0	93.8±4.3	77.2±2.6	68.0	208.1±9.4	115.0±4.1	181.6±7.8	51.8±2.4	139.1	**
ICCV 08302	87.2±4.0	66.0±2.0	107.7±4.3	51.6±2.6	78.1	62.5±9.4	76.2±4.1	65.5±7.8	22.8±2.4	56.7	**
ICCV 92311	83.9±4.0	60.7±2.0	96.2±4.3	52.7±2.6	73.4	66.1±11.3	69.5±4.1	76.1±9.5	35.0±2.4	61.7	**
ICC 15802	56.4±4.0	37.5±2.0	85.6±4.3	48.9±2.6	57.1	54.0±11.3	115.6±4.1	103.9±7.8	39.8±2.4	78.3	**
ICCV 07308	90.5±4.0	65.9±2.0	102.1±5.1	52.8±2.6	77.8	54.8±9.4	55.5±4.1	49.3±9.5	38.9±2.4	49.7	**
ICC 10885©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
ICC 13357©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±2.4	73.6	**
ICC 16654©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
ICC 7315©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.4	73.6	**
ICCV 03309©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.4	73.6	**
ICCV 06304©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
ICCV 08310©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
ICCV 07304©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.6±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
K004©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
K012©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.6	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
ICCV 08313©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
K034©	75.2±10.4	53.9±10.4	92.3±10.4	56.4±10.4	69.4	91.5±34.4	80.6±34.3	75.4±34.4	46.8±34.3	73.6	**
IG 72109	64.1±4.0	39.9±2.0	80.4±4.3	63.6±2.6	62.0	127.6±9.4	96.3±4.1	48.8±7.8	83.8±2.4	89.1	**
ICCV 08303	85.4±4.0	64.0±2.0	101.8±4.3	55.1±2.6	76.6	61.7±9.4	55.4±4.1	57.6±7.8	33.1±2.4	51.9	**
ICCV 95311	67.1±4.0	46.2±2.0	85.5±4.3	53.2±2.6	63.0	92.4±9.4	73.5±4.1	92.4±7.8	40.7±2.4	74.8	**

Continue Table 4.13

K041	78.4±4.0	60.7±2.0	100.0±4.3	51.2±2.6	72.6	62.7±11.3	65.5±4.1	85.4±7.8	40.8±2.4	63.6	**
K022	58.4±4.8	39.1±2.0	82.2±4.3	49.2±2.6	57.2	121.6±11.3	44.1±4.1	59.7±7.8	38.0±2.4	65.8	**
K017	75.6±4.0	56.2±2.0	87.0±4.3	61.2±2.6	70.0	84.3±9.4	70.2±4.1	50.1±7.8	74.4±2.4	69.7	**
K025	81.9±4.8	62.0±2.0	98.3±4.3	52.5±2.6	73.7	68.9±11.3	59.8±4.1	46.1±7.8	38.7±2.4	53.4	**
ICCV 08307	81.2±4.0	61.4±2.0	99.6±4.3	54.6±2.6	74.2	61.7±9.4	61.8±4.1	50.3±7.8	39.9±2.4	53.4	**
ICCV 92318 (Check)	86.1±4.0	58.3±2.0	100.6±4.3	52.8±2.6	74.5	66.9±9.4	42.7±4.1	35.9±7.8	31.3±2.4	44.2	**
ICC 13283	50.5±4.8	39.3±2.0	66.7±4.3	67.3±2.6	56.0	144.6±11.3	38.4±4.1	95.2±7.8	29.8±2.4	77.0	**
K038	84.6±4.0	57.8±2.0	94.2±4.3	49.3±2.6	71.5	47.8±9.4	47.4±4.1	37.2±7.8	19.4±2.4	37.9	**
Mean	75.2	53.9	92.3	56.4	69.4	91.5	80.6	75.4	46.8	73.6	
Minimum	50.5	36.8	66.7	48.9	56.0	47.8	38.4	35.9	19.3	37.9	
Maximum	90.5	66.3	107.7	77.2	78.8	208.1	152.5	181.6	89.6	139.1	

Number of Seeds Pod $^{-1}$

Genotypes and genotypes by environment interactions showed highly significant ($p < 0.0001$) variation for number of seeds pod $^{-1}$ (Table 4.14). Genotypes recorded higher number of seeds pod $^{-1}$ in short rains compared to long rain season at both sites except, K041, IG 71055, ICCV 95311, ICCV 92311; ICCV 00305 and ICC 13764 which recorded higher values in long rain season Kabete. Genotypes with the lowest (ICCV 00402, ICCV 95311, K017 and ICCV 00302) and the highest (ICC 13283, ICC 248, ICCV 07313 and K025) number of seeds pod $^{-1}$ at Juja also produced the lowest and the highest at Kabete. The ranking of genotypes for number of seeds pod $^{-1}$ differed across environment. Eight and twenty five genotypes surpassed the check varieties ICCV 00305 and ICCV 92318 for number of seeds pod $^{-1}$ respectively.

Based on overall means, the genotypes differed with respect to number of seeds pod $^{-1}$. Eight genotypes were classified as low (< 1.3), 24 genotypes as moderate (1.3 – 1.5) and 7 genotypes had high (> 1.5) number of seeds pod $^{-1}$. Genotypes ICC 13283 (1.7) followed by ICC 13461 (1.5), ICC 13764 (1.5), ICC 2482 (1.5) and K025 (1.5) gave the highest values. Genotypes ICCV 00402 (1.2), ICCV 95311 (1.2), ICCV 00302 (1.3), K017 (1.3) and ICCV 08302 (1.3) recorded the lowest values. The check varieties ICCV 00305 (1.4) and ICCV 92318 (1.3) were classified as moderate for number of seeds pod $^{-1}$. With respect to environment wise means, the highest number of seeds pod $^{-1}$ was recorded in short rain season Juja (1.5) followed by long rain season Juja (1.4), short rain season Kabete (1.4) and long rain season Kabete (1.3) with a grand mean of 1.4.

Biomass Yield

There were highly significant ($p < 0.007$) differences among genotypes and genotype by environment interactions for biomass yield ha $^{-1}$ (Table 4.14). Genotypes recorded higher biomass yield ha $^{-1}$ in long rain compared to short rain season at Juja. At Kabete higher biomass yield ha $^{-1}$ was recorded in short rain season except in ICCV 92311, ICCV 08302, ICCV 00305, ICC 13461 and ICC 13283. During the long rain all genotypes recorded higher biomass yield ha $^{-1}$ at Juja compared to Kabete. In short rain, all genotypes except ICC 13283 and ICCV 95311 recorded high biomass yield ha $^{-1}$ at Kabete compared to Juja. Four and thirty seven genotypes exceeded the check varieties ICCV 00305 and ICCV 92318 for biomass yield respectively.

On the basis of overall means, the genotypes had a wide range of variation for biomass yield ha $^{-1}$. Twelve genotypes were classified as low (< 2.1 ton), 19 genotypes as moderate (2.1 – 3.0 ton) and 8 genotypes had high (> 3.0 ton) total biomass yield. Genotype ICC 13764 (3.5 ton) followed by ICCV 00302 (3.4 ton), ICCV 05315 (3.3 ton), ICC 13461 (3.2 ton) and ICC 2482 (3.2 ton) recorded the highest biomass yield ha $^{-1}$ (Table 4.14). Genotypes K038 (1.1 ton), ICCV 92318 (1.3 ton), K025 (1.5 ton) and ICC 13283 (1.6 ton) recorded the lowest biomass yield ha $^{-1}$. The check varieties ICCV 00305 (3.1 ton) and ICCV 92318 (1.3 ton) were classified as high and low in values of biomass yield ha $^{-1}$ respectively. Based on the environment wise means, the highest biomass yield ha $^{-1}$ was recorded in the long rain season at Juja (3.0 ton) followed by short rain season Kabete (2.9 ton) , short rain season Juja (1.8 ton) and long rain season Kabete (1.7 ton) with a grand mean of 2.3 ton.

Table 4.14: Performance of *Kabuli* Genotypes for Number of Seeds Pod $^{-1}$ and Total Biomass ha $^{-1}$ at Juja and Kabete

	Number of Seeds Pod $^{-1}$					Total Biomass in tons ha $^{-1}$					
Genotypes	Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Pr.
ICCV 05315	1.3±0.1	1.4±0.1	1.2±0.1	1.2±0.0	1.3	4.9±0.0	2.2±0.0	2.2±0.0	3.7±0.0	3.3	**
ICC 13461	1.5±0.1	1.5±0.1	1.5±0.1	1.6±0.0	1.5	5.2±0.0	2.0±0.0	3.3±0.0	2.5±0.0	3.2	**
ICCV 07313	1.5±0.1	1.6±0.1	1.3±0.1	1.7±0.0	1.5	3.9±0.0	1.4±0.0	1.6±0.0	4.2±0.0	2.8	**
ICC 13764	1.5±0.1	1.6±0.1	1.6±0.1	1.5±0.0	1.5	4.0±0.0	1.9±0.0	3.1±0.0	4.8±0.0	3.5	**
ICCV 00302	1.3±0.1	1.4±0.1	1.2±0.1	1.2±0.0	1.3	3.9±0.0	2.3±0.0	3.0±0.0	4.4±0.0	3.4	**
ICC 2482	1.5±0.1	1.6±0.1	1.5±0.1	1.5±0.0	1.5	5.2±0.0	1.9±0.0	2.2±0.0	3.6±0.0	3.1	**
ICCV 03404	1.3±0.1	1.5±0.1	1.3±0.1	1.5±0.0	1.4	3.3±0.0	2.4±0.0	1.8±0.0	2.7±0.0	2.6	**
ICCV 00402	1.2±0.1	1.3±0.1	1.2±0.1	1.3±0.0	1.2	2.4±0.0	1.8±0.0	2.3±0.0	2.5±0.0	2.2	**
ICCV 07306	1.4±0.1	1.6±0.1	1.2±0.1	1.5±0.0	1.4	2.3±0.0	2.1±0.0	1.1±0.0	3.7±0.0	2.3	**
ICCV 00305(Check)	1.4±0.1	1.4±0.1	1.3±0.1	1.3±0.0	1.4	4.9±0.0	1.6±0.0	3.1±0.0	2.7±0.0	3.1	**
ICCV 05312	1.4±0.1	1.7±0.1	1.3±0.1	1.8±0.0	1.5	2.6±0.0	1.6±0.0	1.1±0.0	3.5±0.0	2.2	**
IG 71055	1.4±0.1	1.6±0.1	1.2±0.1	1.1±0.0	1.3	3.0±0.0	2.4±0.0	3.2+0.0	4.1±0.0	3.1	**
ICCV 08302	1.3±0.1	1.4±0.1	1.1±0.1	1.2±0.0	1.3	2.0±0.0	1.4±0.0	1.7±0.0	1.4±0.0	1.6	**
ICCV 92311	1.4±0.1	1.6±0.1	1.3±0.1	1.1±0.0	1.3	2.4±0.0	1.5±0.0	4.1±0.0	2.2±0.0	2.5	**
ICC 15802	1.3±0.1	1.4±0.1	1.3±0.1	1.3±0.0	1.3	2.4±0.0	2.0±0.0	2.8±0.0	3.2±0.0	2.6	**
ICCV 07308	1.4±0.1	1.5±0.1	1.2±0.1	1.1±0.0	1.3	2.4±0.0	1.9±0.0	0.8±0.0	2.8±0.0	1.9	**
ICC 10885©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
ICC 13357©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
ICC 16654©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
ICC 7315©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
ICCV 03309©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
ICCV 06304©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
ICCV 08310©	1.4±0.2	1.6±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7+0.0	2.9±0.0	2.3	**
ICCV 07304©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
K004©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
K012©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
ICCV 08313©	1.4±0.2	1.5±0.1	1.3±0.2	1.4±0.0	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
K034©	1.4±0.2	1.5±0.2	1.3±0.2	1.4±0.2	1.4	3.0±0.0	1.8±0.0	1.7±0.0	2.9±0.0	2.3	**
IG 72109	1.4±0.1	1.4±0.1	1.3±0.1	1.4±0.0	1.3	4.7±0.0	1.9±0.0	0.8±0.0	4.9±0.0	3.1	**
ICCV 08303	1.4±0.1	1.5±0.1	1.2±0.1	1.2±0.0	1.3	2.2±0.0	1.4±0.0	0.9±0.0	3.1±0.0	1.9	**
ICCV 95311	1.2±0.1	1.3±0.1	1.3±0.1	1.1±0.0	1.2	2.2±0.0	2.2±0.0	1.5±0.0	2.0+0.0	2.0	**

Continue Table 4.14

K041	1.3+0.1	1.4+0.1	1.4+0.1	1.3+0.0	1.4	2.4+0.0	1.5+0.0	1.7+0.0	2.3+0.0	2.0	**
K022	1.3+0.1	1.3+0.1	1.2+0.1	1.6+0.0	1.3	3.1+0.0	1.4+0.0	0.6+0.0	1.9+0.0	1.8	**
K017	1.3+0.1	1.3+0.1	1.2+0.1	1.4+0.0	1.3	2.2+0.0	1.4+0.0	0.4+0.0	3.4+0.0	1.9	
K025	1.4+0.1	1.6+0.1	1.3+0.1	1.7+0.0	1.5	2.0+0.0	1.5+0.0	0.7+0.0	1.9+0.0	1.5	**
ICCV 08307	1.3+0.1	1.5+0.1	1.2+0.1	1.5+0.0	1.4	1.6+0.0	1.9+0.0	0.8+0.0	2.2+0.0	1.6	**
ICCV 92318 (Check)	1.3+0.1	1.3+0.1	1.2+0.1	1.4+0.0	1.3	1.9+0.0	1.0+0.0	0.6+0.0	1.8+0.0	1.3	**
ICC 13283	1.4+0.1	1.6+0.1	1.7+0.1	1.7+0.0	1.6	2.2+0.0	2.0+0.0	1.0+0.0	0.9+0.0	1.6	**
K038	1.3+0.1	1.5+0.1	1.3+0.1	1.8+0.0	1.5	1.5+0.0	1.0+0.0	0.5+0.0	1.4+0.0	1.1	**
Mean	1.4	1.5	1.3	1.4	1.4	3.0	1.8	1.7	2.9	2.3	
Minimum	1.2	1.3	1.1	1.1	1.2	1.5	1.0	0.4	0.9	1.1	
Maximum	1.5	1.7	1.6	1.8	1.6	5.2	2.4	4.1	4.9	3.5	

Seed Yield

The genotypes and genotype by environment interactions showed highly significant variation ($p < 0.004$) for seed yield ha $^{-1}$ (Table 4.15). Genotypes recorded higher seed yield ha $^{-1}$ in the long rains compared to short rains at both sites, except ICCV 05312, ICCV 05315, ICCV 07306, ICCV 07308, ICCV 07313, ICCV 08302, ICCV 08303, ICCV 08307, ICCV 92318, K017, K038, K022, and K025 which recorded higher values in short rain season at Kabete. In long rain season many genotypes recorded higher seed yield ha $^{-1}$ at Juja compared to Kabete, except for ICC 15802, ICCV 00402, IG 71055 and ICCV 92311. In short rain season higher seed yield ha $^{-1}$ was recorded at Kabete except for ICC 13283, ICC 13461, ICCV 03404, ICCV 92311, ICCV 95311 and IG 71055 which recorded higher values at Juja The ranking of genotypes for seed yield ha $^{-1}$ varied across environments. Seven and thirty seven genotypes surpassed the check varieties ICCV 00305 and ICCV 92318 for seed yield ha $^{-1}$ respectively.

Based on overall means the results indicated a wide range of variation among genotypes with respect to seed yield ha $^{-1}$. Eight genotypes were classified as low (< 0.8 ton), 21 genotypes as moderate (0.8 – 1.0 ton) and 10 genotypes as high (> 1.0 ton) for seed yield ha $^{-1}$. Genotype ICCV 05315 gave the highest seed yield ha $^{-1}$ (1.3 ton) followed by ICC 13461 (1.3 ton), ICCV 07313 (1.2 ton), ICC 13764 (1.1 ton) and ICCV 00302 (1.1 ton). Genotypes K038 (0.4 ton), ICC 13283 (0.5 ton), ICCV 92318 (0.6 ton), ICCV 08307 (0.6 ton) and K025 (0.6 ton) recorded the lowest seed yield. The check varieties ICCV 00305 (1.0 ton) and ICCV 92318 (0.6 ton) were classified as moderate and low in seed yield ha $^{-1}$ respectively. Based on environment wise means, the highest seed yield ha $^{-1}$ was recorded during long rain season Juja (1.4 ton) followed by long rain season Kabete (0.9 ton), short rain season Kabete (0.8) and short rain season Juja (0.5) with a grand mean of 0.9 ton.

Hundred Seed Weight

There were highly significant ($p < 0.003$) differences among genotypes and genotype by environment interactions for 100 seed weight (Table 4.15). Evaluated genotypes, except ICC 13283, ICC 15802, ICCV 05312, ICCV 03404, ICCV 07306, ICCV 07313, ICCV 92311, ICCV 00402, ICCV 00305, ICCV 92318, IG 72109, K017, K022 and K038 recorded higher 100 seed weight in short rain compared to long rain season at Juja. While at Kabete, genotypes recorded higher 100 seed weight during long rain season, except ICC ICCV 05312, ICCV 07308, ICCV 07313, ICCV 08303, ICCV 08307, K022 and K038 compared to short rain season. The genotypes recorded higher 100 seed weight at Kabete compared to Juja in both seasons. Thirty two and thirteen genotypes exceeded the check varieties ICCV 00305 and ICCV 92318 for 100 seed weight respectively.

On the basis of overall means, the studied genotypes differed with respect to 100 seed weight. Five genotypes were classified as low (< 25 g), 21 genotypes as moderate (25.0 – 35.0 g) and 13 genotypes had high (> 35 g) for 100 seed weight. Genotypes K025 (48.4 g), ICCV 08302 (45.3 g), ICCV 08303 (44.6), K041 (44.3 g) and ICCV 07308 (43.7 g) respectively gave the highest 100 seed weight. Genotype ICC 13764 (15.7 g) followed by ICC 13461 (17.4 g), IG 71055 (21.6 g) and ICC 2482 (22.2 g) recorded the lowest for 100 seed weight. The check varieties ICCV 00305 (26.5 g) and ICCV 92318 (34.1 g) were classified as moderate for 100 seed weight. With respect to environment wise means, the highest 100 seed weight was recorded in long rain season Kabete (37.0 g) followed by short rain season Kabete (35.7 g), short rain season Juja (30.1 g) and long rain season Juja (29.8 g) with a grand mean of 33.1 g

Table 4.15: Performances of *Kabuli* Genotypes for Seed Yield ha $^{-1}$ and Hundred Seed Weight at Juja and Kabete

	Seed Yield in tons ha $^{-1}$					Hundred Seed Weight in grams					
Genotypes	Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Long Rain Juja Mean±S.E	Short Rain Juja Mean±S.E	Long Rain Kabete Mean±S.E	Short Rain Kabete Mean±S.E	Overall Mean	Pr.
ICCV 05315	2.3±0.0	0.4±0.0	1.1±0.0	1.5±0.0	1.3	37.4±1.4	37.6±1.0	44.5±1.2	44.4±1.2	41.0	**
ICC 13461	2.3±0.0	0.6±0.0	2.0±0.0	0.4±0.0	1.3	13.9±1.4	15.0±1.0	22.0±1.2	18.5±1.2	17.4	**
ICCV 07313	2.2±0.0	0.3±0.0	0.8±0.0	1.5±0.0	1.2	38.7±1.4	37.8±1.0	44.9±1.2	47.7±1.2	42.3	**
ICC 13764	1.8±0.0	0.5±0.0	1.6±0.0	0.7±0.0	1.1	12.4±1.4	13.6±1.0	19.5±1.2	17.1±1.2	15.7	**
ICCV 00302	1.7±0.0	0.7±0.0	1.4±0.0	0.7±0.0	1.1	24.9±1.4	25.4±1.0	31.1±1.2	30.1±1.2	27.9	**
ICC 2482	2.1±0.0	0.4±0.0	1.2±0.0	0.6±0.0	1.1	16.3±1.6	19.8±1.0	25.3±1.5	27.3±1.2	22.2	**
ICCV 03404	1.2±0.0	1.3±0.0	0.9±0.0	0.7±0.0	1.1	35.1±1.4	34.6±1.0	42.2±1.2	36.1±1.2	37.0	**
ICCV 00402	0.6±0.0	0.5±0.0	1.3±0.0	1.7±0.0	1.0	22.2±1.4	20.8±1.0	33.6±1.2	32.9±1.2	27.4	**
ICCV 07306	1.3±0.0	0.5±0.0	0.5±0.0	1.8±0.0	1.0	31.9±1.4	31.7±1.0	42.7±1.2	38.7±1.2	36.2	**
ICCV 00305(Check)	1.6±0.0	0.4±0.0	1.4±0.0	0.7±0.0	1.0	23.0±1.4	20.8±1.0	31.7±1.2	30.2±1.2	26.5	**
ICCV 05312	1.4±0.0	0.7±0.0	0.6±0.0	1.2±0.0	1.0	36.1±1.4	35.3±1.0	41.5±1.2	42.3±1.2	38.8	**
IG 71055	1.0±0.0	0.7±0.0	1.7±0.0	0.4±0.0	1.0	19.6±1.4	20.1±1.0	27.2±1.2	19.5±1.2	21.6	**
ICCV 08302	1.4±0.0	0.4±0.0	1.0±0.0	1.1±0.0	1.0	42.3±1.4	44.4±1.0	49.4±1.2	45.1±1.2	45.3	**
ICCV 92311	1.2±0.0	0.5±0.0	1.6±0.0	0.4±0.0	0.9	33.7±1.4	33.5±1.0	41.6±1.2	34.4±1.2	35.8	**
ICC 15802	1.2±0.0	0.4±0.0	1.7±0.0	0.6±0.0	0.9	20.6±1.4	20.4±1.0	29.4±1.2	25.0±1.2	23.8	**
ICCV 07308	1.8±0.0	0.5±0.0	0.5±0.0	1.0±0.0	0.9	41.1±1.4	42.7±1.0	45.0±1.5	45.8±1.2	43.6	**
ICC 10885©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
ICC 13357©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
ICC 16654©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
ICC 7315©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
ICCV 03309©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
ICCV 06304©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
ICCV 08310©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
ICCV 07304©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
K004©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37±9.4	35.7±9.4	33.1	**
K012©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
ICCV 08313©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
K034©	1.4±0.0	0.5±0.0	0.9±0.0	0.8±0.0	0.9	29.8±9.4	30.1±9.4	37.0±9.4	35.7±9.4	33.1	**
IG 72109	2.1±0.0	0.5±0.0	0.6±0.0	0.5±0.0	0.9	23.6±1.4	22.0±1.0	31.7±1.2	30.3±1.2	26.9	**
ICCV 08303	1.2±0.0	0.4±0.0	0.5±0.0	1.4±0.0	0.9	40.9±1.4	41.5±1.0	47.4±1.2	48.8±1.2	44.6	**
ICCV 95311	1.5±0.0	0.6±0.0	0.8±0.0	0.4±0.0	0.8	26.3±1.4	27.0±1.0	37.9±1.2	29.2±1.2	30.1	**

Continue Table 4.15

K041	1.0±0.0	0.4±0.0	0.9±0.0	0.7±0.0	0.7	39.9±1.4	43.4±1.0	47.0±1.2	46.8±1.2	44.3	**
K022	1.3±0.0	0.4±0.0	0.4±0.0	0.7±0.0	0.7	33.4±1.6	33.3±1.0	37.1±1.2	43.8±1.2	36.9	**
K017	1.0±0.0	0.4±0.0	0.2±0.0	1.2±0.0	0.7	29.9±1.4	28.4±1.0	40.1±1.5	37.2±1.2	33.9	**
K025	1.0±0.0	0.4±0.0	0.4±0.0	0.6±0.0	0.6	44.3±1.6	45.8±1.0	51.4±1.2	50.9±1.2	48.1	**
ICCV 08307	0.7±0.0	0.4±0.0	0.4±0.0	0.7±0.0	0.6	33.7±1.4	34.6±1.0	38.3±1.2	40.3±1.2	36.7	**
ICCV 92318 (Check)	1.0±0.0	0.3±0.0	0.4±0.0	0.7±0.0	0.6	31.4±1.4	31.0±1.0	37.1±1.2	37.0±1.2	34.1	**
ICC 13283	0.9±0.0	0.3±0.0	0.5±0.0	0.3±0.0	0.5	23.3±1.6	23.0±1.0	32.0±1.2	25.9±1.2	26.0	**
K038	0.6±0.0	0.2±0.0	0.3±0.0	0.5±0.0	0.4	29.5±1.4	28.4±1.0	25.9±1.2	37.1±1.2	30.2	**
Means	1.4	0.5	0.9	0.8	0.9	29.8	30.1	37.0	35.7	33.1	
Minimum	0.6	0.2	0.2	0.3	0.4	12.4	13.6	19.5	17.1	15.7	
Maximum	2.3	1.3	2.0	1.8	1.3	44.3	45.8	51.4	50.9	48.1	

4.2.3. Qualitative Characters of *Kabuli* Chickpea

The results on eight qualitative traits showed a wide range of variation among *kabuli* genotypes (Figure 4.2) for all characters, except for leaf type (normal) and pod dehiscence (non-dehiscence) for which genotypes were monomorphic. Genotypes were polymorphic with respect to stem pigmentation and were classified as dark green (59 %), light green (38.0 %) and partly purple (3.0 %) (Figure 4.2A).The results indicated four types of growth habit namely semi erect, semi- spreading, spreading and prostrate. Semi spreading (46.0 %) trait recorded the highest frequency followed by spreading (28.0 %) and semi- erect (21.0 %) while prostrate (5.0 %) recorded the lowest (Figure 4.2B). Genotypes also showed variations for seed testa texture with smooth (79.0 %) having the highest value followed by tuberculated (18.0 %) and rough trait with a values of three percent (Figure 4.2C). There were differences among genotypes for flower colour like white (97.0 %) and light pink (3.0 %) (Figure 4.2D). The evaluated genotypes varied with respect to seed shape as follows: owl's head (92.0 %), pea shaped (5.0 %) and angular (3.0 %) (Figure 4.2E). The genotypes also showed variability for seed coat colour with majority having creamy white (97 %) and three percent being brown (Figure 2F).

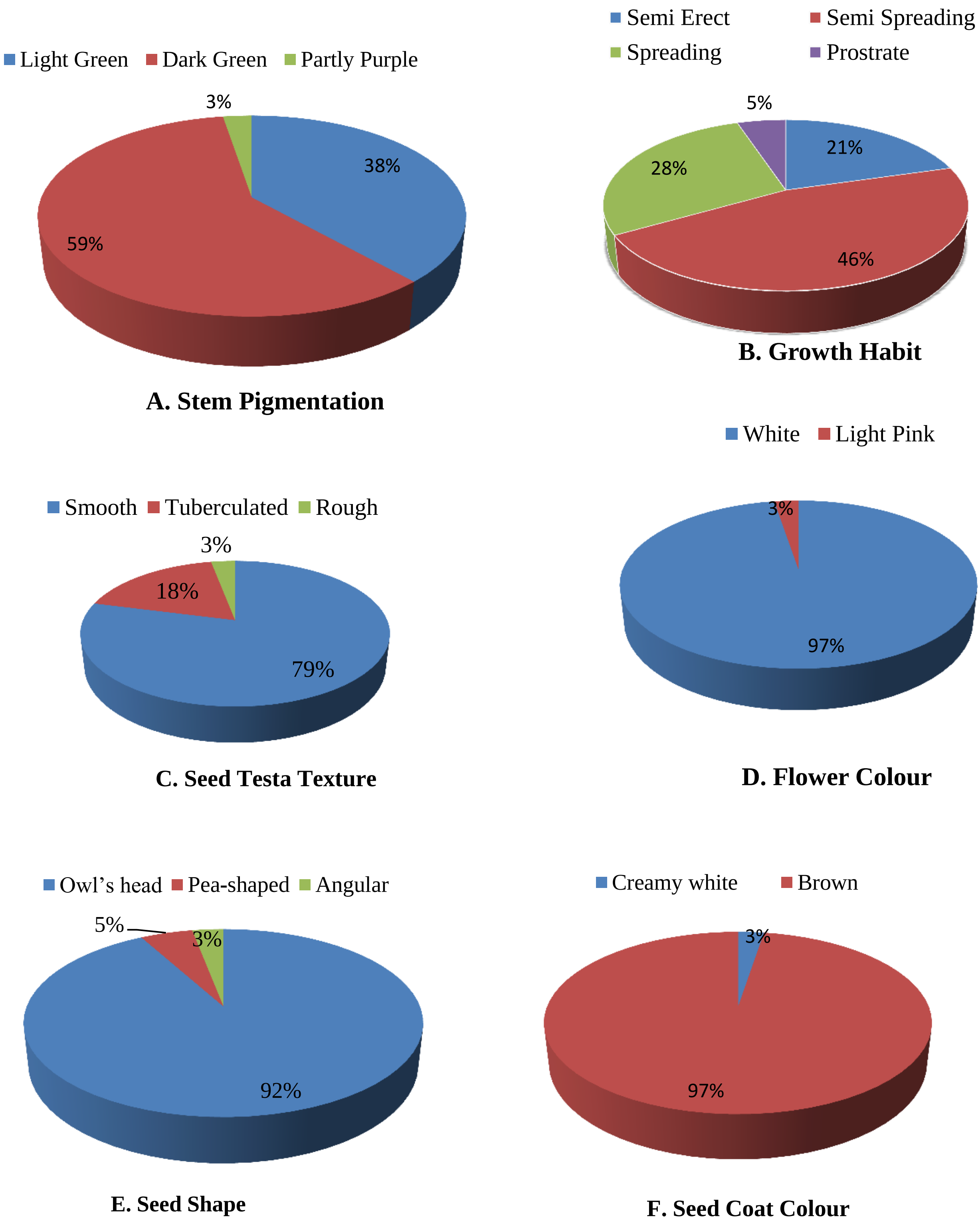

Figure 4.2: Distribution of Qualitative Characters among *Kabuli* Chickpea at Juja and Kabete

4.2.4. Correlation among Quantitative Traits of *Kabuli* Genotypes

The environment wise correlation coefficients are given in appendices (VII, VIII, IX, X). While across environments correlation coefficient are presented in (Table 4.16). There was positive (Table 4.16) and highly significant ($p < 0.01$) correlation of seed yield ha $^{-1}$ with total biomass yield ha $^{-1}$ (r = 0.85 **), number of pods plant $^{-1}$ (r = 0.57**), plant canopy width (r = 0.39**) and secondary branches plant $^{-1}$ (r = 0.34*) but was not significantly correlated with other traits.

Total biomass yield ha $^{-1}$ had positive and highly significant ($p < 0.01$) correlation with days to 50 % flowering (r = 0.39**), days to 50 % podding (r = 0.38*), plant canopy width (r = 0.60**), plant height (r = 0.38*), primary branches plant $^{-1}$ (r = 0.55**), number of secondary branches plant $^{-1}$ (r = 0.56**), number of pods plant $^{-1}$(r = 0.75**) and days to 75 % maturity (r = 0.53**). Total biomass yield ha $^{-1}$ was also negatively significant correlated with 100 seed weight (r = - 0.53**) but not significantly correlated with other traits.

The number of pods plant $^{-1}$ showed positive and highly significant ($p < 0.01$) correlation with days to 50 % flowering (r = 0.65**), days to 50 % podding (r = 0.71**), plant canopy width (r = 0.68**), plant height (r = 0.56**), number of primary branches plant $^{-1}$ (r = 0.74**), secondary branches plant $^{-1}$ (r = 0.78**), days to 75 % maturity (r = 0.79**) but was negatively correlated with pod filling period (r = - 0.50**) and 100 seed weight (r = - 0.70**).

Days to 75 % maturity was positively and highly significantly ($p < 0.01$) correlated with days to 50 % flowering (r = 0.83**), days to 50 % podding (r = 0.89**), plant canopy width (r = 0.63**), plant height (r = 0.62**), number of primary branches plant $^{-1}$ (r = 0.81**) and secondary branches plant $^{-1}$ (r = 0.78**) but was negatively significant with pod filling period (r = - 0.63**) and 100 seed weight (r = - 0.78**) and not significantly correlated with other traits.

Days to 50 % podding was positively and highly significantly ($p < 0.01$) correlated with days to 50 % flowering (r = 0.96**), plant height with days to 50 % flowering (r = 0.45**), days to 50 % podding (r = 0.50**) and plant canopy width (r = 0.77**).

Table 4.16: Correlation Coefficient among Quantitative Characters of *Kabuli* Genotypes at Juja and Kabete

	DF	DP	PCW	PH	NPB	NSB	DM	PFP	NPP^{-1}	NSP^{-1}	BM	SY	HSW
DF	1												
DP	0.96**	1											
PCW	0.62**	0.61**	1										
PH	0.45**	0.50**	0.77**	1									
NPB	0.77**	0.78**	0.78**	0.72**	1								
NSB	0.72**	0.75**	0.72**	0.69**	0.88**	1							
DM	0.83**	0.89**	0.63**	0.62**	0.81**	0.78**	1						
PFP	-0.95**	-0.88**	-0.54**	-0.30**	-0.66**	-0.61**	-0.63**	1					
NPP^{-1}	0.65**	0.71**	0.68**	0.56**	0.74**	0.78**	0.79**	-0.50**	1				
NSP^{-1}	0.19NS	0.17NS	0.39**	0.31*	0.25NS	0.23NS	0.18NS	-0.20NS	0.11NS	1			
BM	0.39**	0.38*	0.60**	0.38*	0.55**	0.56**	0.53**	-0.28NS	0.75**	0.09NS	1		
SY	0.08NS	0.06NS	0.39**	0.12NS	0.29NS	0.34*	0.22NS	0.00NS	0.57**	-0.03NS	0.85**	1	
HSW	-0.81**	-0.82	-0.60**	-0.41**	-0.64**	-0.62**	-0.78**	0.71**	-0.70**	-0.22NS	-0.53**	-0.22NS	1

Note: **- significant at 1 % level of significant (l. o. s) ($Pr < 0.01$), * - significant at 5 % level of significant ($Pr < 0.05$) and NS – non - significant at 5 % ($Pr > 0.05$)

DF- days to 50 % flowering, DP - days to 50 % podding , PCW - plant canopy width, PH - plant height, NPB - number of primary branches plant $^{-1}$, NSB - number of secondary branches plant $^{-1}$, DM - days to 75% maturity, PFP- pod filling period, NPP $^{-1}$ number of pods plant $^{-1}$,NSP $^{-1}$ – Number of seeds pod $^{-1}$, BM – total biomass ha $^{-1}$, SY – seed yield ha^{-1} and HSW- hundred seed weight

CHAPTER FIVE

5.0. DISCUSSION

5.1. 1. Agronomic Traits of *Desi* Chickpea

Crop germplasm for chickpea is a valuable source of genetic diversity that is anticipated to be highly useful for direct and future breeding programmes. The success in genetic improvement of chickpea greatly relies on the availability of genetic resources and their genetic variations. Knowledge of genetic variations among genotypes and relationships of economic traits would assist chickpea breeders to devise suitable breeding strategies and to develop adapted and productive varieties. The genotypes evaluated in this study showed wide variations for all characters studied, thus indicating the existence of wide diversity among the germplasm. The diversity for various traits is as described below:

Days to 50 % flowering

Flowering time is an important stage in chickpea crop development. Environmental conditions during this critical reproductive stage have a significant impact on the ultimate seed yield. Results from this study showed highly significant differences for days to 50 % flowering (Table 4.1). These results were similar to those of Parameshwarappa *et al*. (2012) who reported highly significant differences for days to 50 % flowering among chickpea germplasm. Other studies in chickpea, (Khan, Farhatulla & Khan, 2011; Gul *et al.,* 2013) have reported significant genetic variability for days to 50 % flowering though the genotypes in those studies took longer to flower (141.0 – 156.7 days and 90 – 122 days respectively). In other legumes, Imani *et al.* (2013) and Oladejo *et al*. (2011) reported high genetic variation with respect to days to 50 % flowering in lentil and cowpea germplasm. The present results are in disagreement with those of Zelalem (2014) who reported non-significant variations for days to 50 % flowering in haricot bean.

Flowering stage is highly sensitive and may be influenced by extreme temperatures due to adverse effect on viability of pollen and pollination which could result to poor fertilization and low seed set.

Number of Leaflet leaf $^{-1}$ at Podding

Genotypes showed significant differences with respect to number of leaflet leaf $^{-1}$ at podding (Table 4.1). The results were in agreement with those of Farshadfar and Farshadfar (2008) and Khan, Farhatullah and Khan., (2011) who reported significant variation for number of leaf leaflet leaf $^{-1}$ in chickpea germplasm. In lentil, Imani *et al.* (2013) also reported highly significant difference for number of leaf let leaf $^{-1}$.

The present results indicated the potential of the germplasm in obtaining genotypes with higher number of leaflet leaf $^{-1}$at podding. High number of leaflet leaf $^{-1}$at podding might contribute to increased total leaf area plant $^{-1}$ and to photosynthesis and consequently the final yield perform as required.

Plant Canopy Width

The studied genotypes exhibited a wide range of variations for plant canopy width (Table 4.2). These findings were in agreement with those of Malik *et al.* (2010) who reported substantial variations for plant canopy width among chickpea germplasm. Similarily Upadhyaya *et al*. (2011) reported significant wide variation for plant width in chickpea germplasm. Enlargement of plant canopy width could be attributed to higher number of primary and secondary branches plant $^{-1}$ and tall plant height and could lead to increased number of pod plant $^{-1}$ and hence final seed yield.

Plant Height

Plant height is one of the desirable characters in chickpea. Results from this study showed wide variability for plant height among genotypes (Table 4.3). The results were in agreement with previous studies in chickpea; (Kayan & Saitadak, 2012, Parameshwarappa *et al*., 2012, Khan, Farhatullah & Khan, 2011, Tesfamichael *et al*., 2014) who studied other chickpea genotypes.

All genotypes recorded taller plant height in Juja compared to Kabete. The recorded variation on plant height could be contributed due to uncultivated land which had high organic matter used as a fertilizer and clay soil with high water holding capacity compared to Kabete with reddish or brown highly cultivated soil. Genotypes with short and medium plant height along with reasonable yield related traits could be utilized for further chickpea breeding programme.

Number of primary branches plant $^{-1}$

The studied genotypes showed highly significant variations for number of primary branches plant $^{-1}$ (Table 4.3). These results were similar to those of (Ali & Ahsan, 2012, Gul *et al.*, 2013, Qureshi *et al.*, 2004) who reported highly significant variations for number of primary branches plant $^{-1}$ in other chickpea genotypes. These results contradict those of Hegde (2011) who reported low number of primary branches plant $^{-1}$ (2 - 3) in chickpea and Tabasum *et al*. (2010) who reported non-significant differences for number of primary branches plant $^{-1}$ in mungbean germplasm. All genotypes recorded the higher number of primary branches plant $^{-1}$ at Juja compared to Kabete. These could be attributed to difference genotypes, growing in environment and genotype by environment interaction. High number of primary branches plant $^{-1}$ may increase the number of secondary branches plant $^{-1}$ and number of pods plant $^{-1}$. These could probably lead to increased ultimate yield ha $^{-1}$

Number of Secondary Branches Plant $^{-1}$

The present findings showed substantial variations for number of secondary branches plant $^{-1}$ among genotypes (Table 4.4). These results were in agreement with those of Gul *et al*. (2013) and Hegde (2011) who reported highly significant and wide range of variability for number of secondary branches plant $^{-1}$ in chickpea. Similar findings were reported in cowpea by Imran *et al*. (2010). The results contradict those of Malik *et al.* (2010) who reported low number of secondary branches plant $^{-1}$ (2 – 10) compared to these results.

All genotypes recorded the higher number of primary branches plant $^{-1}$ at Juja compared to Kabete. These could be attributed to difference on genetic makeup of genotypes, growing environment factor and genotype by environment interactions. Genotypes ranking for number of secondary branches plant $^{-1}$varied across environments which indicated no specific genotypes were consistently superior across environment. High number of secondary branches plant $^{-1}$ and larger plant canopy width could result in high number of pods plant $^{-1}$ and this could contribute to increased final seed yield.

Days to 75 % Maturity

Crop phenology (flowering and maturity) plays a key role in increasing seed yield in chickpea. Breeding for earliness is one of the main breeding objectives in chickpea, as most farmers usually seek for early maturing varieties in order to enable the crop to escape biotic and abiotic stresses that occur late in the growing season. In addition, earliness trait could provide an opportunity for dual cropping and high yield per unit time and increase the total yield per unit area. The results from this study showed highly significant differences for days to 75 % maturity among studied genotypes (Table 4.4). These findings were in agreement with those of Khan, Farhatullah and Khan (2011) in chickpea, Oladejo *et al*. (2011) in cowpea and Imani *et al*. (2013) in lentil. However, these results contradict with those of Malik *et al.*

(2010) in chickpea and Zelalem (2014) in haricot beans who reported non-significant variation for days to maturity.

All the genotypes took longer time to mature in the long rain seasons compared to short rain seasons at both sites. In addition, all studied genotypes took longer time to mature at Kabete compared to Juja in both seasons. These could be attributed to the fact that low temperature during growing season delayed crop development and results delayed in maturity time and crop duration. During these experiments Kabete was cooler than Juja as well as long rain season was cooler than short rain seasons in both sites. The variation for days to maturity indicated the potential of the evaluated genotypes to obtain early and moderate maturing variety in with reasonable yield.

Pod Filling Period

Pod filling period is the continuation of vegetative and reproductive phase and the main stage which determines the pod size, seed size (weight) and hence final seed yield.

The evaluated genotypes showed highly significant variation with respect to pod filling period (Table 4.5). Previous studies in chickpea reported similar results for pod filling period (Khamssi *et al*., 2011). In cowpea, Imani *et al.* (2013) reported highly significant variation for pod filling period.

All genotypes took a shorter pod filling period in the short rains as compared to long rains at Juja and Kabete. Comparatively high temperatures at Juja compared with Kabete site could be contributed to short vegetative stage duration and leads reproductive stages. Hence pod filling period took short at Juja and short rain seasons in both sites.

Early and medium pod filling period genotypes from this study could benefit earliness and enables the varieties to escape late occurring abiotic and biotic stresses in the semi-arid areas parts of the region.

5.1.2. Yield and Yield related Characters

Number of Pods Plant $^{-1}$

Generally plant growth behavior and yield performance of pulse crop including chickpea can be determined by number of effective pods plant $^{-1}$. This study showed existence of significant variations for number of pods plant $^{-1}$ among genotypes (Table 4.5). Similarly Kayan and Saitadak (2012) reported highly significant and wide range of variation for number of pods plant $^{-1}$ in chickpea germplasm. Likewise, Malik *et al.* (2010), Qureshi *et al*. (2004), Gul *et al*. (2013) reported significant variations for this trait in chickpea germplasm. In cowpea, Hegde and Mishra (2009) reported significant differences for pods peduncle $^{-1}$ and other useful agronomic traits. The evaluated genotypes recorded higher mean number of pods plant $^{-1}$ in the long rain season at Juja as compared to long rain season at Kabete. The recorded variation in sites and seasons could be highly contributed to environmental factors than genotypes differences. Cool temperature during plant growth favours more vegetative than reproductive branches and hence results low number of pods plant $^{-1}$.This study indicates there is a potential of obtaining high pod yielding genotypes from the evaluated germplasm. The identified high pod yielding genotypes could be used as parents for future hybridization. Increased number of pod plant $^{-1}$ could result from high effective number of primary and secondary branches plant $^{-1}$ and usually high pod yielding genotypes give increased seed yield as long as other factors are conducive.

Number of Seed Pod $^{-1}$

The studied genotypes showed highly significant difference for number of seeds pod $^{-1}$ (Table 4.6). A previous study in chickpea, Gul *et al*. (2013) reported highly significant variations for number of seeds pod $^{-1}$. Likewise, Qureshi *et al.* (2004) and Hegde (2011) have reported significant and wide variations for number of seeds pod $^{-1}$. Increased number of seeds pod $^{-1}$ could contribute to enhancement of the ultimate seed yield and vice versa. The presence of genetic variations for number of seeds pod $^{-1}$ could be used by chickpea breeders in the region.

Total Biomass

Total biomass or biological yield results from the combined effect of biological and physiological processes which take place during growth and development of the plant. Total biomass indicates the potential of the specific genotypes to convert the photosynthates into dry matter. Genotypes showed highly significant differences and wide variations for biomass ha $^{-1}$ that indicated considerable diversity (Table 4.6). Similarly Malik *et al*. (2010) reported that significant variations among genotypes for biomass yield in chickpea germplasm. In different legumes, Latief *et al*. (2011) and Stoilva and Pereira (2013) reported highly significant differences for biomass yield in lentil and cowpea germplasm respectively.

The genotypes recorded higher total biomass yield ha $^{-1}$ during long rains compared to short rain season at Juja. The recorded high total biomass during long rain season was probably contributed by more vegetative growth due cool temperature than short rain season. Higher total biomass yield could be contributed through more number of primary and secondary branches plant $^{-1}$, tall plant height and large plant canopy width and hence increase the final seed yield

Genotypes with high total biomass yield ha $^{-1}$, modest phenology and reasonable yield traits could be exploited in future chickpea breeding programmes in the region.

Seed Yield

Seed yield is a quantitative trait and the result of various physiological and biochemical processes in the plant. Seed yield ha $^{-1}$ is one of the main criteria for identifying and selecting superior varieties for release to the farmers. There were highly significant differences among evaluated genotypes in this study for seed yield ha $^{-1}$ (Table 4.7). In confirmation the current results (Farshadfar & Farshadfar, 2008; Malik *et al.,* 2009) reported substantial range of variation for seed yield in other chickpea genotypes. In other legumes, many studies (Roy *et al.*, 2013; Hegde & Mishra, 2009; Furat & Uzun, 2010) reported significant difference for seed yield in lentil, cowpea and sesame germplasm respectively. However, these results contradict with those of Oladejo *et al*. (2011) who reported non-significant differences for seed yield in cowpea genotypes. Promising and high seed yielding genotypes were identified and could be released as varieties or used future hybridization. The top five high yielding genotypes were ICC 9636 (1.8 ton), ICCV 97105 (1.8 ton), ICCV 00108 (1.8 ton), ICC 6579 (1.7 ton) and ICC 5639 (1.7 ton).

Hundred Seed Weight

Seed weight is one of the most important yield related traits in pulse crops and determines the final seed size. The results from this study showed highly significant differences for 100 seed weight among genotypes (Table 4.7). Likewise Qureshi *et al*. (2004); Malik *et al*. (2009) and Khan, Farhatullah and Khan (2011) reported significant and wide range of variation for 100 seed weight among chickpea germplasm.

The recorded wide genetic variation could be attributed to the use of diverse genotypes which differed in pod size and pod filling period which affect the seed weight. Higher number of pods plant $^{-1}$ could result in reduced seed size (weight) due to competition for nutrients and moisture. The results from this study proved that genotype ICC 13124 (33.8 g) with lower number of pods plant $^{-1}$ (101.1) recorded the highest 100 seed weight across environment. The top most genotypes with higher 100 seed weight were ICC 13124 (33.8 g) followed by ICC 6877 (28.6 g), ICC 11903 (28.1 g) and ICCV 07111 (26.2 g). This indicated the potential of obtaining genotypes with high seed size and reasonable yield traits from the studied germplasm.

5.1.3. Qualitative Traits *Desi* Genotypes

The recorded qualitative traits showed wide variations among *desi* genotypes (Figure 4.1). Majority of the evaluated genotypes were semi- spreading and had brown seed coat colour, dark pink flowers, partly purple pigmented, angular seed shape and rough testa texture. Similarly Ramanappa *et al.* (2013), Upadhyaya *et al*. (2002), Qureshi *et al.* (2004) and Hedge (2011) reported significantly wide variations for growth habit (erect, semi erect and semi spreading, spreading), seed shape (angular, pea-shaped), seed testa texture (rough, smooth and tuberculated), seed coat colour (black to green), flower colour (pink, white) among chickpea germplasm. In cowpea, Stoilva and Pereira (2013) reported existence of wide variation for qualitative traits. These results contradict those of Furat and Uzun (2010) who reported the presence of monomorphic variations for branching habit, flower color, growth habit and capsule dehiscence in sesame accessions. The inheritance of qualitative traits is controlled by one major gene, whose expression is not influenced by environmental factors. Genetic variation also is the main interest of plant breeders and hence the recorded variations from this study can be utilized in future breeding programmes for improvement of chickpea.

5.1.4. Correlation

Yield improvement can be achieved through direct selection for seed yield or by indirect selection through yield related characters. Characters to be considered for indirect selection, yield improvement should be positively and significantly correlated with seed yield. Analysis of agronomic and yield related traits and their correlation towards seed yield could provide a good opportunity for effective indirect selection of high yielding genotypes. The results from this study, showed there was positive and highly significant correlation of seed yield ha $^{-1}$ with total biomass yield ha $^{-1}$, number of primary and secondary branches plant $^{-1}$, pod filling period and number of pods plant $^{-1}$ but not significant correlation with 100 seed weight and plant height (Table 4.8). The results therefore implied that increased seed yield ha $^{-1}$ was not due to heavier 100 seed weight and tall plant height but from increased biomass yield ha $^{-1}$, high number of pods plant $^{-1}$, longer pod filling period, more number of primary and secondary branches plant $^{-1}$. According to Qureshi *et al.* (2004), characters with positive and significant correlation with yield could be used for indirect selection of high yielding genotypes without evaluating for yield *per se*.

Similar studies in chickpea, have reported positive and significant correlation of seed yield with number of primary and secondary branches plant $^{-1}$, number of pods plant $^{-1}$and biomass yield (Malik *et al*., 2014), seed yield with biomass yield and harvest index (Ahmad *et al*., 2012). In chickpea, Ali *et al*. (2011) reported negative and non-significant correlation of seed yield with plant height.

The results from this study further showed negatively significant correlation of seed yield with days to 50 % flowering and days to 50 % podding. Likewise Khan and Bangulzai (2006) reported that negative and significant correlation of seed yield with days to 50 % flowering and days to 50 % podding in pea cultivars. However, these results contradict with those of Vaghela *et al.* (2009) who reported positive and significant correlation of seed yield ha $^{-1}$ with 100 seed weight in chickpea. Negative correlation of seed yield with days to 50 % flowering and days to 50 % podding could be due to the fact that early flowering and podding genotypes utilize only a short period for photosynthates and this leads to low ultimate yield. These indicated that short growth plant could be contributed greatly to low final yield compared to medium and late growth plant. Generally short growth duration gives low yields compared to medium and long growth duration. In chickpea, Namvar and Sharifi (2011) reported high biomass and seed yield obtained from medium and longer growth period compared to shorter growth. In marginal rainfall areas, earliness enables genotypes to escape from biotic and abiotic stresses that occur late in the growing season.

Total biomass yield ha $^{-1}$ was positively and significantly correlated with plant canopy width, plant height, number of primary branches plant $^{-1}$, number of secondary branches plant $^{-1}$, days to 75 % maturity and number of pods plant $^{-1}$ (Table 4.8). Similar results were reported by Qureshi *et al.* (2004) in chickpea, Miheretu *et al*. (2013) in coriander and Aghili *et al*. (2012) in lentil germplasm. A positive and significant correlation between seed yield ha^{-1} and total biomass yield ha^{-1} indicates that both of these characters could be selected and improved simultaneously. In those circumstances, where chickpea is produced as forage for livestock feed, it could be a good opportunity to select for dual purpose genotypes with high biomass yield ha^{-1} and seed yield ha^{-1}. Besides, larger plant canopy width, tall plant height, more number of primary and secondary branches $plant^{-1}$, high number of pods $plant^{-1}$ and late maturity could be associated with high biomass yield ha^{-1} and these characters could be improved concurrently. Other positively and significantly correlated traits (Table 4.8) are as follows:

Number of pods $plant^{-1}$ positively and highly significantly correlated with plant canopy width, plant height, number of primary and secondary branches $plant^{-1}$, days to 75 % maturity and pod filling period while it had negatively non- significant correlation with 100 seed weight. Larger plant canopy width and higher number of primary and secondary branches $plant^{-1}$, late maturity and late pod filling period could be contributed to more number of pods $plant^{-1}$ and seed yield. There was positive and highly significant correlation of days to 75 % maturity with days to 50 % flowering, days to 50 % podding, plant canopy width, plant height, number of primary and secondary branches $plant^{-1}$, number of pods $plant^{-1}$ and total biomass yield ha^{-1}. These indicated that early flowering and podding genotypes were not only early maturing but they had small plant canopy width, short plant height, low number of primary and secondary branches $plant^{-1}$ with less number of pods $plant^{-1}$ and low biomass yield ha^{-1} and vice versa. Malik *et al*. (2014) reported positive and significant correlation of days to maturity with number of primary branches $plant^{-1}$, number of secondary branches $plant^{-1}$ and number of pods $plant^{-1}$.

Overall the results from this study indicated wide variability among the assessed genotypes with respect to all studied characters. These indicated that appreciable diversity existed with in the chickpea germplasm and could be exploited by chickpea breeders in the region. The wide diversity could be contributed to genotype, environment and genotype by environment interactions. The ranking of genotypes for various traits varied across environments. This showed the presence of a crossover type of genotype by environment interactions. High yielding genotypes across environments identified in this study include ICC 9636 (1.8 ton), ICC 6579

(1.7 ton), ICC 5639 (1.7 ton), ICC 1052 (1.6 ton) and ICC 15614 (1.6 ton) *desi* chickpea. These genotypes could be recommended for release to the farmers in the region.

Positively and significantly correlated traits could be used for effective indirect selection of high yielding genotypes from the germplasm.

5.2.1. Agronomic Traits of *Kabuli* Chickpea

Days to 50 % flowering

Earliness character is important in chickpea crop breeding. Information on the variation available for days to flowering could be enabled chickpea germplasm collections to be efficiently conserved and exploited in future breeding programme. The results from this study showed significant variation among *kabuli* genotypes for days to 50 % flowering (Table 4.9). Studies in chickpea by Khan, Farhatullah and Khan (2011); Gul *et al.* (2013) and Tesfamichael *et al.* (2014) reported that significant and wide range of variation for days to 50 % flowering among chickpea germplasm. However, the current results were not in agreement with those of Zelalem (2014) who reported non-significant variations for days to 50 % flowering in haricot bean.

Most genotypes took longer time to flower in the long rain season compared to short rain season at Juja except ICC 2482. These indicated that the variation was caused due to environmental factor than genotypes differences. Generally cool temperature delays phenological stages and crop duration.

Thus early flowering genotypes from this study could be used as parent for hybridization by chickpea breeders in the region to develop varieties with modest flowering and reasonable yield traits.

Plant Height

The evaluated genotypes showed significant and wide variability with respect to plant height (Table 4.11). Similar results were reported by Kayan and Saitadak (2012) and Tesfamichael *et al*. (2014) in chickpea genotypes and Imani *et al*. (2013) in lentil genotypes. These results were in disagreement with those of Roy *et al.* (2013) who reported non-significant variation for plant height in lentil germplasm.

The studied genotypes recorded taller plant height during long rains compared to short rain season at Juja. Relatively cooler environment favours to vegetative growth such as high plant height and more branches than reproductive stages. Thus the long rain seasons had comparatively low average temperature and could be caused tall plant height growth. The recorded variation in plant height could be contributed to genotype differences, environment and genotype by environment interactions. The existence of wide variation for plant height can be exploited in chickpea breeding programmes aimed to develop medium plant height varieties with reasonable seed yield ha $^{-1}$.

Days to 75 % Maturity

Earliness trait is one of the prime breeding goals in chickpea as most farmers generally search for early maturing varieties in order to enable the crop to mature within the growing season and give reasonable seed yield. The current results showed substantial differences for days to 75 % maturity (Table 4.12). Similar findings were reported by Tesfamichael *et al*., (2014) in chickpea, Oladejo *et al*. (2011) in cowpea and Imani *et al*., (2013) in lentil. These results were contradictory with those reported by Malik *et al.* (2010) in chickpea and Zelalem (2014) in haricot beans. The ranking of genotypes for days to maturity differed across environments. Genotypes varied in their response to maturity across environment where genotypes matured early in Juja may not be early maturing in Kabete and vice versa. Egesel and Kahriman (2013) reported that early maturing genotypes performed better in drought stress than late maturing genotypes and suggested that earliness criteria of selection for selecting suitable varieties for drought prone areas. Therefore early and moderate maturing genotypes from this study can be used to develop varieties with moderate maturity time and reasonable yield related traits.

5.2.2. Yield and Yield related Characters

Number of Pods Plant $^{-1}$

Plant growth behavior and yield performance of pulse crops like chickpea could be determined by number of effective pods plant $^{-1}$. In this study genotypes showed significant variation with respect to number of pods plant $^{-1}$ (Table 4.13). Similar results were reported by many researchers (Malik *et al.,* 2010; Gul *et al*., 2013, Ramanappa et al., 2013, Tesfamichael *et al.*, 2014) in chickpea germplasm and (Hegde &Mishra, 2009) in cowpea germplasm.

Genotypes ranking for number of pods plant $^{-1}$varied across environments. The genotypes which performed better in Juja did not necessarily perform well. The recorded higher number of primary and secondary branches plant $^{-1}$ probably contributed to increased number of pods plant $^{-1}$ and increased number of pods plant $^{-1}$ could be results in increased ultimate yield. The wide variation recorded in this study can be utilized in future chickpea breeding programme in East African regions.

Total Biomass

Total biological yield is a quantitative trait results from the cumulative effect of biological and physiological processes that take place during plant growth and development. Total biomass in plant indicated the potential of the specific genotypes to convert the photosynthates into dry matter. Genotypes showed highly significant and wide range of variations for total biomass yield ha $^{-1}$ that indicated presence of considerable diversity (Table 4.14). Similarly, Malik *et al*. (2010) reported that significant variations among genotypes for biomass yield in chickpea germplasm. In other legumes, Latief *et al*. (2011) and Stoilva and Pereira (2013) reported highly significant differences for biomass yield in lentil and cowpea germplasm respectively.

High total biomass yielding genotypes could be contributed direct proportional to increased seed yield due to the ability to convert photosynthates in to dry matter and seed yield. Generally total biological yield is the most important trait which could be contributed to the final grain yield due to its close relationship. Toker and Cagirgan (2004) reported that increased total biomass yield lead to increased seed yield in chickpea germplasm. Therefore, genotypes with high total biomass yield ha $^{-1}$, moderate phenology and reasonable seed yield traits from this study can be utilized in future chickpea breeding programmes in Eastern Africa regions.

Seed Yield

Yield trait is a quantitative variable and the result of several physiological and biochemical processes in the crop growth and development stages. The results from this study indicated substantial differences among genotypes for seed yield ha $^{-1}$ (Table 4.15). The presence of wide variations for seed yield ha $^{-1}$ showed the potential of the evaluated germplasm to develop high yielding varieties for specific and broad adaptation. In chickpea, previous studies have reported significant variation for seed yield (Malik *et al.*, 2009, Tesfamichael *et al*., 2014). However, the present results contradict with those of Oladejo *et al*. (2011) who reported non-significant differences for seed yield in cowpea genotypes.

During the short rain season higher seed yield ha $^{-1}$ was recorded at Kabete except for ICC 13283, ICC 13461, ICCV 03404, ICCV 92311, ICCV 95311 and IG 71055 which recorded higher values at Juja. These indicated the genotypes and environment effect played a great role for seed yield and genotypes showed specific adaptation to particular environment. The ranking of genotypes for seed yield ha $^{-1}$ varied across environments. The evaluated genotypes showed different responses which indicated no specific genotypes were superior across environments.

High seed yield ha $^{-1}$ is one of the main criteria for identifying and selecting superior varieties for release to farmers. The top five high yielding identified genotypes were ICCV 05315 (1.3 ton); ICC 13461 (1.3 ton), ICCV 07313 (1.2 ton), ICC 13764 (1.1 ton) and ICCV 00302 (1.1 ton). Genotypes with reasonable seed yield ha $^{-1}$ combined with moderate maturity could be selected for future hybridization Thus, high yielding genotypes from the studied germplasm could be used directly by the farmers or used for future improvement of chickpea in the region.

Hundred Seed Weight

Seed weight is one of the most important yield related traits in pulse crops including chickpea and determines the final seed weight and ultimate seed yield. The evaluated genotypes showed significant variation with respect to100 seed weight (Table 4.15). Similarly Ramanappa et al. (2013), Atta *et al*. (2008), and Tesfamichael *et al*. (2014) reported wide and significant variation for 100 seed weight among chickpea germplasm. Seed size trait is one of the main yield related characters in chickpea and could attribute to the final seed weight. In the current study large seeded genotypes gave more 100 seed weight compared to small seeded genotypes. The recorded significant variation for 100 seed weight could be attributed to diverse genotypes for seed size. The variation in seed size and seed weight could be contributed significant to final seed yield ha $^{-1}$. Bicer (2009) reported 4 -6 % increase in seed weight from large seeded genotypes compared to medium seeded genotypes in chickpea germplasm. The top five genotypes with higher 100 seed weight were K025 (48.4 g), ICCV 08302 (45.3 g), ICCV 08303 (44.6 g) K041 (44.3 g) and ICCV 07308 (43.7 g). The variation from this study implied the potential of obtaining genotypes with higher seed size and reasonable yield traits from the studied germplasm.

5.2.3. Qualitative Traits *Kabuli* Genotypes

The results on qualitative traits showed wide differences among evaluated genotypes (Figure 4.2). Most of the tested genotypes had semi- spreading growth habit, creamy white seed coat colour, white flower colour, dark green stem colour and owl's head seed shape with smooth testa texture. In confirmation of the current results Upadhyaya *et al*. (2002), Qureshi *et al.* (2004), Hedge (2011) and Ramanappa *et al.* (2013), reported significant variations for growth habit (semi erect, semi spreading, spreading and prostrate), seed shape (angular, owl's head, pea-shaped), seed testa texture (rough, smooth and tuberculated), seed coat colour (black to green), flower colour (pink, white) in chickpea germplasm. Similarly Qureshi *et al*. (2004), reported existence of considerable variation for growth habit, flower colour and seed testa texture and seed shape. These results contradict those of Furat and Uzun (2010) who reported the presence of monomorphic variations for branching habit, flower color, growth habit and capsule dehiscence in sesame accessions.

Theoretically, qualitative characters are controlled by a few genes with large effects and the expressions of these traits are more likely to be constant across environments. Genetic variation is the main interest of plant breeders and these variations can be utilized in future breeding programmes for improvement of chickpea.

5.2.4. Correlation

Yield trait is one of the main criteria for selection of superior varieties for release to the farmers, however yield related traits are also important in plant breeding to improve seed yield along with other economic traits. Yield enhancement can be obtained through direct selection for seed yield or by indirect selection through yield related traits. Traits should be positively and significantly correlated with seed yield for ease yield improvement via indirect selection. Determination of yield related traits and their correlation towards seed yield could create an opportunity for effective indirect selection of superior genotypes. The current results showed there was positive and significant correlation of seed yield ha $^{-1}$ with biomass yield ha $^{-1}$, plant canopy width , number of secondary branches plant $^{-1}$ and number of pods plant $^{-1}$ but not significant correlation with other traits (Table 4.16). The results therefore clearly indicated that increased seed yield ha $^{-1}$ could be as a result of increased total biomass yield ha $^{-1}$, high number of pods plant $^{-1}$, more number of secondary branches plant $^{-1}$and larger plant canopy width. These characters can be improved simultaneously and used for indirect selection to enhance breeding efficiency in chickpea. According to Qureshi *et al.* (2004), traits with positive and significant correlation with yield could be used for indirect selection of high yielding varieties without evaluating for yield *per se*.

Similarly study in chickpea, has reported positive and significant correlation of seed yield with plant canopy width, number of secondary branches plant $^{-1}$, number of pods plant $^{-1}$and biomass yield (Malik *et al*., 2014). Ali *et al*. (2012) reported negative and non-significant correlation of seed yield with plant height. The results from this study showed non- significant correlation of seed yield with number of primary branches plant $^{-1}$, days to maturity and hundred seed weight. These results contradict with those of Vaghela *et al.* (2009) who reported positive and significant correlation of seed yield ha $^{-1}$ with 100 seed weight in chickpea. Similarly Padmavathi *et al*. (2013) reported that seed yield positively and significantly correlated with plant height, number of primary branches plant $^{-1}$, number of secondary branches plant $^{-1}$, number of pods per plant, 100-seed weight.

Total biomass yield ha $^{-1}$ was positively and significantly correlated with days to 50% flowering and days to 50 % podding, plant canopy width, plant height, number of primary and secondary branches plant $^{-1}$, days to 75 % maturity and number of pods plant $^{-1}$ (Table 4.16). Similar results were reported by Qureshi *et al.* (2004) in chickpea and Aghili *et al*. (2012) in lentil germplasm. The positive and significant correlation among seed yield ha^{-1} and total biomass yield ha^{-1} implies that both of these characters could be selected and improved concurrently. In those conditions, where chickpea is produced as forage for livestock feed, it could be a good opportunity to select for dual purpose genotypes with high total biomass yield ha $^{-1}$ and seed yield ha $^{-1}$. Besides, larger plant canopy width, tall plant height, more number of primary and secondary branches plant $^{-1}$, high number of pods plant $^{-1}$, late flowering , late podding and late maturity could be associated with high total biomass yield ha $^{-1}$ and these characters could be improved simultaneously. Other positively and significantly correlated traits are described below:

Number of pods plant $^{-1}$ positively and highly significantly correlated with days to 50 % flowering, days to 50 % podding, plant canopy width, plant height, number of primary and secondary branches plant $^{-1}$, days to 75 % maturity and negatively correlated with pod filling period while it had not- significant correlation with other traits. Tall plant height, larger plant canopy width, more primary and secondary branches plant $^{-1}$, late flowering, late podding and late maturity could be contributed to more number of pods plant $^{-1}$ and final seed yield.

There was positive and highly significant correlation of days to 75 % maturity with days to 50 % flowering, days to 50 % podding, plant canopy width, plant height, number of primary and secondary branches plant $^{-1}$, number of pods plant $^{-1}$ and biomass yield ha $^{-1}$. These indicated that early flowering and podding genotypes had small plant canopy width, short plant height, low number of primary and secondary branches plant $^{-1}$ with less number of pods plant $^{-1}$ and low biomass yield ha $^{-1}$ and vice versa. Malik *et al*. (2014) reported positive and significant correlation of days to maturity with number of primary branches plant $^{-1}$, number of secondary branches plant $^{-1}$ and number of pods plant $^{-1}$.

In brief, the results from this study showed wide variation among the assessed genotypes for all studied characters. This implied that considerable diversity existed with in the chickpea germplasm and could be utilized by chickpea breeders in the region. This wide variation could be attributed to genotype, environment and genotype by environment interactions. The ranking of genotypes for most agronomic traits differed across environments. This indicated the presence of a crossover type of genotype by environment interactions. High yielding genotypes across environments identified in this study include ICCV 05315 (1.3 ton), ICC 13461 (1.3 ton), ICCV 07313 (1.3 ton), ICC 13764 (1.1 ton) and ICCV 00302 (1.1 ton) *kabuli* chickpea. These superior genotypes could be recommended for release to the farmers in the region and could be exploited for future yield improvement in *kabuli* chickpea. Moreover, the characters positively and significantly correlated with seed yield could be reliable selection criteria and used for efficient indirect selection of high yielding genotypes of chickpea from the evaluated germplasm.

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Chickpea is an important pulse crop in Eastern Africa. The crop is well adapted for growth in the semi- arid parts of the region. There is limited information on characterization of chickpea germplasm from the region. The objectives of this study were to evaluate the diversity among genotypes and determine association among agronomic traits and with seed yield.

Results from this study indicated the following;

- Wide diversity was recorded with respect to all studied characters.
- The ranking of genotypes for yield performance varied across environments. This could be attributed to a crossover type of genotype by environment interactions.
- The highest yield was recorded in long rain season at Juja followed by long rain season at Kabete and short rain season at Kabete in both *desi* and *kabuli* types
- High yielding genotypes namely ICC 9636, ICC 6579, ICC 5639, ICC 1052 and ICC 15614 from *desi t*ype and ICCV 05315, ICC 13461, ICCV 07313, ICC 13764 and ICCV 00302 from *kabuli* type of chickpea were identified
- Evaluated genotypes exceeded the check varieties for most agronomic traits studied in both *desi* and *kabuli* chickpea.
- Seed yield was positively and significantly correlated with total biomass yield, number of primary and secondary branches plant $^{-1}$, pod filling period and number of pods plant in *desi* chickpea indicating that these characters could be used for indirect selection of superior genotypes.
- Seed yield was negatively correlated with days to flowering and days to podding, indicating that such traits could not be improved concurrently.
- Seed yield was positively and significantly correlated with total biomass yield ha $^{-1}$, number of pods plant $^{-1}$, plant canopy width and secondary branches plant $^{-1}$ in *kabuli* type of chickpea.
- The evaluated *desi* and *kabuli* types varied for six out of eight qualitative traits.

- Thus the information on diversity and correlation among agro-morphological traits could enable breeders in the region to devise suitable breeding strategy.

6.2. Recommendations

This study was conducted in Juja and Kabete using *desi* and *kabuli* chickpea genotypes. The results indicated wide diversity among genotypes with respect to all traits studied. However, most of the studied traits were highly influenced by variations in environmental conditions from one location to another and from one season to another. For a better understanding of this germplasm the following activities are recommended;

- Further studies need to be conducted using molecular markers which are not affected by variations in environmental factors.
- The germplasm needs to be evaluated in more environments especially in the drier parts of the country in order to identify better genotypes for those regions.
- The germplasm needs to be assessed for variation in nutritional and cooking properties.

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APPENDICES

Appendix i: Metrological data at Juja and Kabete in 2013 and first quarter of 2014

	Kabete			Juja		
Month	Rain fall (mm)	Maximum Temp- (°C)	Minimum Temp (°C)	Rain fall (mm)	Maximum Temp (°C)	Minimum Temp (°C)
Jan-2013	45.12	23.9	13.9	73.31	26.6	14.2
Feb-2013	0	25.5	13.6	0.01	28.5	13.4
Mar-2013	175.2	25.1	15.0	214.14	28.1	15.3
Apr-2013	508.8	24.1	14.9	429.4	25.7	15.9
May-2013	50.7	22.7	13.7	20.6	26.4	14.7
June-2013	20.33	20.8	11.9	9.14	24.1	13.4
July-2013	5.41	22.4	11.0	1.6	24.6	11.9
Augu-2013	46.61	0	0	6.6	23.6	12.8
Sept-2013	259.0	24.5	12.2	9.9	27.7	13.3
Mean	123.5	21.0	11.8	85.0	26.1	13.9
Octo-2013	7.6	25.6	13.3	1.4	29.1	14.2
Nov-2013	128.4	23.6	14.5	113.4	26.7	15.4
Decer-2013	163.2	27.9	14.1	110.2	26.7	14.4
Jan-2014	30.2	25.1	13.4	0	28.7	12.5
Feb-2014	146.5	25.1	14.3	96.3	28.6	14.8
Mar-2014	81.7	23	14.2	128.4	28.1	15.9
Mean	92.9	25.1	14.0	75.0	28.0	14.5

Source: (Kenyan Metrological Station, 2013).

Appendix ii: Variation among *Desi* Genotypes for Days to Podding and Leaflet leaf $^{-1}$ at Flowering at Juja and Kabete

	Days to 50% Podding					Number of leaflet leaf $^{-1}$ at flowering				
	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall	Long rain Juja	Short rain Juja	Long rain Kabete	Short rain Kabete	Overall
Genotypes	Mean±S.E	Mean±S.E	Mean±S.E	Mean±S.E	Mean	Mean±S.E	Mean±S.E	Mean±S.E	Mean+S.E	Mean
Annigeri	81.6±5.5	64.9±5.5	78.2±5.6	62.7±5.5	71.9	13.8±0.8	14.0±0.8	13.4±0.8	13.8±0.8	13.7
ICC 1052	80.3±2.0	61.0±1.5	74.7±3.8	68.1±1.3	71.0	13.6±0.3	13.7±0.3	13.0±0.3	13.1±1.3	13.3
ICC 10685	73.9±2.0	61.7±1.5	71.6±3.6	57.4±1.3	66.1	12.1±0.3	12.3±0.3	11.5±0.3	12.4±0.3	12.1
ICC 11198	85.2±2.0	67.5±1.5	84.6±3.6	65.7±1.3	75.8	13.5±0.3	12.9±0.3	12.6±0.3	13.2±0.3	13.1
ICC 1164	83.2±2.0	66.4±1.5	83.2±3.6	71.6±1.3	76.1	14.7±0.3	14.4±0.3	14.0±0.3	14.3±0.3	14.4
ICC 11903	89.3±2.0	69.7±1.5	86.6±3.6	74.0±1.3	79.9	15.0±0.3	14.7±0.3	14.2±0.3	14.4±0.3	14.6
ICC 11944	88.0±2.0	69.2±1.5	88.0±3.6	68.3±1.3	78.4	14.2±0.3	14.1±0.3	13.4±0.3	13.7±0.3	13.9
ICC 12851	78.9±2.0	62.7±1.5	74.8±3.6	61.0+1.3	69.3	13.9±0.3	14.3±0.3	13.3±0.3	13.4±0.3	13.7
ICC 12928	86.4±2.0	70.1±1.5	90.8±3.6	75.0±1.3	80.6	14.2±0.3	14.2±0.3	13.5±0.3	13.8±0.3	13.9
ICC 13124	83.8±2.0	63.8±1.5	74.7±3.6	61.7±1.3	71.0	13.5±0.3	14.1±0.3	13.5±0.3	13.7±0.3	13.7
ICC 1356	78.5±2.0	61.5±1.5	72.8±3.6	54.6±1.3	66.8	13.7±0.3	14.2±0.3	13.7±0.3	14.0±0.3	13.9
ICC 1392	83.1±2.0	65.7±1.5	78.6±3.6	64.9±1.3	73.1	14.2±0.3	14.2±0.3	13.7±0.3	14.2±0.3	14.1
ICC 1397	84.8±2.4	67.8±1.5	83.8±3.8	60.6±1.3	74.2	13.8±0.3	13.8±0.3	12.9±0.3	13.7±0.3	13.6
ICC 8200	81.6±5.5	64.9±5.5	78.2±5.6	62.7±5.5	71.9	13.8±0.8	14.0±0.8	13.4±0.8	13.8±0.8	13.7
ICC 1398	78.8±2.0	60.4±1.5	72.0±3.6	56.0±1.3	66.8	14.2±0.3	14.3±0.3	13.5±0.3	14.0±0.3	14.0
ICC 4918	81.6±5.5	64.9±5.5	78.2±5.5	62.7±5.5	71.9	13.8±0.8	14.0±0.8	13.4±0.8	13.8±0.8	13.7
ICC 14051	77.6±2.0	61.9±1.5	73.6±3.6	58.5±1.3	67.9	13.8±0.3	14.0±0.3	13.4±0.3	13.9±0.3	13.8
ICC 1422	77.4±2.0	64.7±1.5	72.7±3.8	57.3±1.3	68.0	15.5±0.3	15.6±0.3	14.8±0.3	15.3±0.3	15.3
ICC 14815	81.3±2.0	66.0±1.5	83.3±3.6	70.3±1.3	75.2	13.5±0.3	12.9±0.3	12.9±0.3	13.0±0.3	13.1
ICC 1510	87.2±2.0	68.6±1.5	85.0±3.6	63.4±1.3	76.1	15.0±0.3	15.0±0.3	14.7±0.3	15.2±0.3	15.0
ICC 6294	81.6±5.5	64.9±5.5	78.2±5.6	62.7±5.5	71.9	13.8±0.3	14.0±0.8	13.4±0.8	13.8±0.8	13.7
ICC 15614	76.4±2.0	63.5±1.5	72.9±3.6	62.7±1.3	68.9	14.3±0.3	14.9±0.3	14.6±0.3	14.6±0.3	14.6
ICC 16261	84.0±2.0	63.9±1.5	82.2±3.6	56.8±1.3	71.7	13.8±0.3	14.3±0.3	13.4±0.3	13.5±0.3	13.8
ICC 16524	76.2±2.0	61.2±1.5	74.7±3.6	55.1±1.3	66.8	13.4±0.3	13.6±0.3	12.7±0.3	13.4±0.3	13.3
ICC 16915	74.3±2.0	61.4±1.5	72.2±3.6	55.6±1.3	65.9	13.4±0.3	14.2±0.3	13.0±0.3	13.3±0.3	13.5
ICC 1715	81.2±2.0	66.5±1.5	81.5±3.6	62.5±1.3	72.9	14.6±0.3	14.3±0.3	13.8±0.3	14.4±0.3	14.2
ICC 2242	85.9±2.0	70.0±1.5	89.3±3.6	73.1±1.3	79.6	13.8±0.3	13.8±0.3	13.0±0.3	13.7±0.3	13.6
ICC 2580	76.7±2.0	65.9±1.5	72.9±3.6	56.4±1.3	68.0	13.5±0.3	13.7±0.3	13.1±0.3	13.5±0.3	13.5
ICC 3325	78.2±2.0	66.6±1.5	75.6±3.6	56.3±1.3	69.1	13.5±0.3	13.1±0.3	13.2±0.3	13.2±0.3	13.2

Continue Appendix ii

ICC 4093	77.3±2.0	60.1±1.5	72.2±3.6	57.5±1.3	66.8	13.6±0.3	13.8±0.3	12.9±0.3	13.2±0.3	13.4
ICC 4182	83.0±2.0	59.1±1.5	75.4±3.6	68.2±1.3	71.4	14.2±0.3	14.3±0.3	13.5±0.3	13.8±0.3	14.0
ICC 4463	86.4±2.0	63.4±1.5	76.8±3.6	63.9±1.3	72.6	14.0±0.3	14.9±0.3	13.7±0.3	14.1±0.3	14.2
ICC 4657	88.7±2.0	65.9±1.5	84.3±3.6	66.7±1.3	76.4	13.5±0.3	13.5±0.3	13.1±0.3	13.3±0.3	13.4
ICC 4872	79.6±2.0	61.7±1.5	75.0±3.6	57.4±1.3	68.4	14.0±0.3	14.4±0.3	13.7±0.3	14.2±0.3	14.1
ICC 4991	78.9±2.0	64.6±1.5	75.7±3.6	57.4±1.3	69.1	13.3±0.3	14.3±0.3	13.6±0.3	13.8±0.3	13.8
ICC 506	78.8±2.0	65.0±1.5	71.9±3.6	63.3±1.3	69.8	13.9±0.3	13.9±0.3	13.4±0.3	13.7±0.3	13.7
ICC 5504	85.5±2.0	64.9±1.5	80.8±3.6	61.0±1.3	73.0	13.3±0.3	13.9±0.3	13.1±0.3	13.6±0.3	13.5
ICC 5613	82.3±2.0	64.1±1.5	74.9±3.6	56.6±1.3	69.5	13.9±0.3	14.1±0.3	13.6±0.3	14.2±0.3	13.9
ICC 5639	85.8±2.0	67.5±1.5	85.2±3.6	74.1±1.3	78.2	15.0±0.3	14.9±0.3	14.4±0.3	14.1±0.3	14.6
ICC 6579	77.7±2.0	63.2±1.5	76.7±3.6	67.3±1.3	71.2	13.5±0.3	13.8±0.3	13.0±0.3	13.7±0.3	13.5
ICC 6877	86.7±2.0	68.2±1.5	85.5±3.6	67.0±1.3	76.8	13.9±0.3	13.6±0.3	13.5±0.3	13.4±0.3	13.6
ICC 7326	82.2±2.0	65.3±1.5	79.2±3.6	70.2±1.3	74.2	13.6±0.3	14.2±0.3	13.5±0.3	13.5±0.3	13.7
ICC 7413	77.9±2.4	62.9±1.5	70.2±3.6	56.6±1.3	66.9	13.2±0.3	13.9±0.3	13.1±0.3	13.2±0.3	13.4
ICC 7867	81.7±2.0	65.3±1.5	78.0±3.6	63.3±1.3	72.1	13.4±0.3	13.6±0.3	12.6±0.3	13.3±0.3	13.2
ICC 791	92.7±2.0	73.4±1.5	91.9±3.6	69.9±1.3	81.9	13.5±0.3	13.1±0.3	12.1±0.3	13.4±0.3	13.0
ICC 8318	78.0±2.0	61.2±1.5	69.0±3.6	57.7±1.3	66.5	13.5±0.3	13.9±0.3	13.4±0.3	13.5±0.3	13.6
ICC 8522	78.7±2.0	62.0±1.5	72.4±3.6	60.9±1.3	68.5	12.8±0.3	13.6±0.3	12.7±0.3	13.2±0.3	13.1
ICC 9002	84.3±2.0	69.0±1.5	84.0±3.6	69.6±1.3	76.7	13.9±0.3	13.8±0.3	13.0±0.3	13.6±0.3	13.6
ICC 9636	83.5±2.0	67.5±1.5	86.3±3.6	73.2±1.3	77.6	16.3±0.3	16.0±0.3	15.9±0.3	16.4±0.3	16.2
ICC 9702	86.7±2.0	70.2±1.5	82.6±3.6	68.8±1.3	77.1	13.9±0.3	14.0±0.3	13.4±0.3	13.6±0.3	13.7
ICC 9712	80.9±2.0	66.3±1.5	80.7±3.6	66.1±1.3	73.5	13.9±0.3	14.0±0.3	13.4±0.3	13.3±0.3	13.6
ICC 9862	83.4±2.0	66.2±1.5	78.7±3.8	60.7±1.3	72.2	13.2±0.3	13.5±0.3	12.5±0.3	13.4±0.3	13.1
ICC 9872	79.4±2.0	63.5±1.5	76.4±3.6	58.3±1.3	69.4	12.9±0.3	13.2±0.3	12.6±0.3	13.0±0.3	12.9
ICC 9895	83.2±2.4	64.4±1.5	75.4±3.8	63.2±1.3	71.6	12.7±0.3	13.3±0.3	12.3±0.3	12.9±0.3	12.8
ICCV 07102	81.6±5.5	64.9±5.5	78.2±5.6	62.7±5.5	71.9	13.8±0.8	14.0±0.8	13.4±0.8	13.8±0.8	13.7
ICCV 00108(check)	75.8±2.0	64.4±1.5	71.6±3.6	58.1±1.3	67.5	13.6±0.3	13.8±0.3	13.3±0.3	13.4±0.3	13.5
ICCV 07111	83.6±2.0	59.0±1.5	73.3±3.6	52.5±1.3	67.1	15.0±0.3	15.3±0.3	14.4±0.3	15.7±0.3	15.1
ICCV 10	79.8±2.0	63.2±1.5	71.0±3.6	54.9±1.3	67.2	13.7±0.3	13.9±0.3	13.1±0.3	13.6±0.3	13.6
ICCV 00104	81.6±5.5	64.9±5.5	78.2±5.6	62.7±5.5	71.9	13.8±0.8	14.0±0.8	13.4±0.8	13.8±0.8	13.7
ICCV 97105(check)	75.9±2.0	67.9±1.5	74.1±3.6	56.5±1.3	68.6	13.2±0.3	13.4±0.3	13.1±0.3	13.4±0.3	13.3

Appendix iii: Correlation Coefficient among Quantitative Characters of *Desi* Genotypes in Long Rain Season at Juja

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1.Days to Flowering	1											
2. Days to Podding	0.86**	1										
3.Plant Height	0.25NS	-0.01NS	1									
4.Primary Branches	0.16NS	0.06NS	0.07NS	1								
5.Secondary Branches	0.28*	0.14NS	0.36**	0.55**	1							
6. Days to Maturity	0.27*	0.43**	0.08NS	-0.24NS	-0.16NS	1						
7. Pod Filling Period	-0.93**	-0.73**	-0.25NS	-0.21NS	-0.33**	0.09NS	1					
8. Pods Plant $^{-1}$	0.17NS	0.08NS	0.44**	0.2NS	0.44**	0.18NS	-0.1NS	1				
9. Seed Plant $^{-1}$	0.28*	0.11NS	-0.07NS	0NS	-0.08NS	0.12NS	-0.24NS	0.02NS	1			
10. Total Biomass	0NS	-0.15NS	0.32*	0.51**	0.44**	-0.02NS	0.02NS	0.35**	0.06NS	1		
11. Seed Yield	-0.25NS	-0.36**	0.07NS	0.46**	0.32*	-0.27*	0.19NS	0.21NS	0.09NS	0.83**	1	
12. Hundred Seed Weight	-0.13NS	-0.02NS	0.26*	-0.14NS	0.02NS	-0.12NS	0.03NS	0.08NS	-0.55**	-0.05NS	-0.07NS	1
13. Plant Canopy Width	0.22NS	-0.02NS	0.87**	0.11NS	0.48**	0.1NS	-0.2NS	0.61**	-0.07NS	0.3*	0.09NS	0.17NS

Note: ** - significant at 1% level of significant (Pr < 0.01), * - significant at 5% level of significant (Pr <0.05) and NS - non-significant at 5% level of significant (Pr > = 0.05)

Appendix iv: Correlation Coefficient among Quantitative Characters of *Desi* Genotypes in Short Rain Season at Juja

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1. Days to Flowering	1											
2.Days to Podding	0.75**	1										
3.Plant Height	0.04NS	-0.12NS	1									
4. Primary Branches	0.21NS	-0.04NS	0.38**	1								
5.Secondary Branches	0.16NS	-0.1NS	0.39**	0.85**	1							
6. Days to Maturity	0.59**	0.31*	0.35**	0.54**	0.47**	1						
7. Pod Filling Period	-0.79**	-0.69**	0.22NS	0.16NS	0.16NS	0.04NS	1					
8. Pods Plant $^{-1}$	-0.29*	-0.45**	0.43**	0.56**	0.65**	0.25NS	0.55**	1				
9. Seeds Pod $^{-1}$	0.05NS	-0.02NS	-0.1NS	-0.16NS	-0.07NS	0.07NS	-0.01NS	-0.14NS	1			
10. Total Biomass	0.16NS	-0.18NS	0.6**	0.55**	0.55**	0.59**	0.26*	0.53**	0NS	1		
11. Seed Yield	-0.16NS	-0.38**	0.38**	0.36**	0.42**	0.37**	0.48**	0.53**	0.22NS	0.76**	1	
12. Hundred Seed Weight	0.06NS	0.1NS	0.09NS	-0.15NS	-0.17NS	-0.06NS	-0.12NS	-0.24NS	-0.09NS	-0.08NS	-0.04NS	1
13. Plant Canopy Width	0.21NS	-0.01NS	0.86**	0.44**	0.45**	0.46**	0.09NS	0.46**	-0.2NS	0.64**	0.39**	-0.03NS

Appendix v: Correlation Coefficient among Quantitative Characters of *Desi* Genotypes in Long Rain Season Kabete

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1.Days to Flowering	1											
2.Days to Podding	0.94**	1										
3.Plant Height	-0.24NS	-0.16NS	1									
4. Primary Branches	0.24NS	0.27*	0.09NS	1								
5.Secondary Branches	0.27*	0.31*	0.03NS	0.85**	1							
6. Days to Maturity	0.35**	0.26*	-0.29*	0.24NS	0.32*	1						
7. Pod Filling Period	-0.96**	-0.9**	0.18NS	-0.17NS	-0.19NS	-0.12NS	1					
8. Pods Plant $^{-1}$	0.05NS	0.09NS	0.33**	0.63**	0.62**	0.22NS	-0.01NS	1				
9. Seeds Pod $^{-1}$	0.22NS	0.22NS	-0.18NS	-0.14NS	-0.22NS	0.1NS	-0.22NS	-0.19NS	1			
10. Total Biomass	-0.11NS	-0.1NS	0.22NS	0.64**	0.56**	0.31*	0.22NS	0.55**	-0.08NS	1		
11. Seed Yield	-0.17NS	-0.19NS	0.15NS	0.59**	0.51**	0.29*	0.27*	0.48**	-0.02NS	0.95**	1	
12. Hundred Seed Weight	-0.32*	-0.3*	0.24NS	-0.08NS	-0.12NS	-0.13NS	0.3*	-0.03NS	-0.52**	0.06NS	0.1NS	1
13. Plant Canopy Width	-0.27*	-0.2NS	0.91**	0.15NS	0.08NS	-0.22NS	0.23NS	0.46**	-0.2NS	0.3*	0.2NS	0.13NS

Appendix vi: Correlation Coefficient among Quantitative Characters of *Desi* Genotypes in Short Rain Season Kabete

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1.Days to Flowering	1											
2.Days to Podding	0.77**	1										
3.Plant Height	0.18NS	0.13NS	1									
4. Primary Branches	0.51**	0.49**	0.18NS	1								
5.Secondary Branches	0.49**	0.54**	0.04NS	0.51**	1							
6. Days to Maturity	0.48**	0.43**	0.59**	0.39**	0.3*	1						
7. Pod Filling Period	0.08NS	0.13NS	0.59**	0.2NS	0.11NS	0.91**	1					
8. Pods Plant $^{-1}$	0.2NS	0.26*	0.24NS	0.49**	0.49**	0.43**	0.40**	1				
9. Seeds Pod $^{-1}$	0.03NS	0.19NS	-0.08NS	0.22NS	0.21NS	0.01NS	-0.01NS	0.22NS	1			
10. Total Biomass	0.3*	0.32*	0.29*	0.36**	0.21NS	0.34**	0.25NS	0.49**	0.25NS	1		
11. Seed Yield	-0.35**	-0.35**	-0.12NS	-0.29*	-0.3*	-0.25NS	-0.12NS	0.02NS	0.18NS	0.46**	1	
12. Hundred Seed Weight	-0.18NS	-0.29*	-0.02NS	-0.33*	-0.24NS	-0.23NS	-0.18NS	-0.36**	-0.57**	-0.29*	-0.04NS	1
13. Plant Canopy Width	0.21NS	0.14NS	0.81**	0.22NS	0.08NS	0.63**	0.62**	0.3*	-0.07NS	0.15NS	-0.28*	0.1NS

Appendix vii: Correlation Coefficient among Quantitative Characters of *Kabuli* Genotypes in Long Rain Season at Juja

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1.Days to Flowering	1											
2.Days to Podding	0.96**	1										
3.Plant Canopy Width	0.51**	0.55**	1									
4.Plant Height	0.47**	0.52**	0.69**	1								
5. Primary Branches	0.52**	0.54**	0.58**	0.65**	1							
6. Secondary Branches	0.71**	0.7**	0.53**	0.65**	0.81**	1						
7. Days to Maturity	0.78**	0.78**	0.5**	0.54**	0.39*	0.58**	1					
8. Pod Filling Period	-0.97**	-0.94**	-0.48**	-0.43**	-0.55**	-0.7**	-0.63**	1				
9. Pods Plant $^{-1}$	0.64**	0.65**	0.37*	0.57**	0.48**	0.62**	0.7**	-0.58**	1			
10. Seeds Plant $^{-1}$	0.15NS	0.14NS	0.5**	0.42**	0.32*	0.2NS	0.37*	-0.11NS	0.43**	1		
11.Total Biomass	0.42**	0.43**	0.67**	0.57**	0.53**	0.56**	0.53**	-0.35*	0.46**	0.49**	1	
12. Seed Yield	0.24NS	0.16NS	0.47**	0.38*	0.38*	0.39*	0.43**	-0.13NS	0.33*	0.51**	0.85**	1
13. Hundred Seed Weight	-0.79**	-0.8**	-0.59**	-0.44**	-0.46**	-0.57**	-0.74**	0.73**	-0.46**	-0.24NS	-0.47**	-0.2NS

Appendix viii: Correlation Coefficient among Quantitative Characters of *Kabuli* Genotypes in Short Rain Season at Juja

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1.Days to Flowering	1											
2.Days to Podding	0.96**	1										
3. Plant Canopy Width	0.41*	0.3NS	1									
4. Plant Height	0.29NS	0.23NS	0.5**	1								
5. Primary Branches	0.71**	0.63**	0.64**	0.58**	1							
6. Secondary Branches	0.66**	0.57**	0.72**	0.51**	0.78**	1						
7. Days to Maturity	0.78**	0.79**	0.32*	0.38*	0.61**	0.53**	1					
8. Pod Filling Period	-0.95**	-0.9**	-0.39*	-0.21NS	-0.65**	-0.62**	-0.55**	1				
9. Pods Plant $^{-1}$	0.3NS	0.36*	0.25NS	0.3NS	0.29NS	0.35*	0.53**	-0.14NS	1			
10. Seed Yield $^{-1}$	-0.02NS	-0.13NS	0.37*	0.18NS	0.18NS	0.29NS	-0.01NS	0.02NS	-0.1NS	1		
11. Total Biomass	0.41**	0.47**	0.49**	0.46**	0.56**	0.62**	0.56**	-0.28NS	0.52**	0.07NS	1	
12. Seed Yield	-0.02NS	0.02NS	0.09NS	0.36*	0.18NS	0.02NS	0.2NS	0.13NS	0.26NS	0.11NS	0.61**	1
13. Hundred Seed Weight	-0.79**	-0.81**	-0.29NS	-0.27NS	-0.49**	-0.47**	-0.64**	0.74**	-0.49**	0NS	-0.38*	-0.08NS

Appendix ix: Correlation Coefficient among Quantitative Characters of *Kabuli* Genotypes in Long Rain Kabete

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1.Days to flowering	1											
2.Days to Podding	0.96**	1										
3.Plant Canopy Width	0.45**	0.5**	1									
4. Plant Height	0.35*	0.41*	0.72**	1								
5. Primary Branches	0.68**	0.77**	0.73**	0.65**	1							
6. Secondary Branches	0.7**	0.73**	0.67**	0.57**	0.88**	1						
7. Days to Maturity	0.55**	0.69**	0.36*	0.34*	0.59**	0.45**	1					
8. Pod Filling Period	-0.96**	-0.87**	-0.41*	-0.31NS	-0.59**	-0.64**	-0.31NS	1				
9. Pods Plant $^{-1}$	0.53**	0.62**	0.79**	0.59**	0.87**	0.76**	0.53**	-0.43**	1			
10. Seeds Pod $^{-1}$	0.51**	0.49**	0.48**	0.53**	0.47**	0.49**	0.08NS	-0.57**	0.37*	1		
11. Total Biomass	0.21NS	0.26NS	0.81**	0.51**	0.63**	0.55**	0.32*	-0.14NS	0.73**	0.27NS	1	
12. Seed Yield	0.3NS	0.35*	0.84**	0.56**	0.7**	0.68**	0.36*	-0.23NS	0.79**	0.31NS	0.96**	1
13. Hundred Seed Weight	-0.7**	-0.69**	-0.48**	-0.35*	-0.56**	-0.68**	-0.41**	0.66**	-0.58**	-0.47**	-0.42**	-0.51**

Appendix x: Correlation Coefficient among Quantitative Characters of *Kabuli* Genotypes in Short Rain Season at Kabete

Characters	1	2	3	4	5	6	7	8	9	101	11	12
1.Days to Flowering	1											
2. Days to Podding	0.64**	1										
3. Plant Canopy Width	0.42**	0.32*	1									
4. Plant Height	0.2NS	0.47**	0.65**	1								
5. Primary Branches	0.25NS	0.7**	0.45**	0.56**	1							
6. Secondary Branches	0.2NS	0.54**	0.42**	0.62**	0.78**	1						
7. Days to Maturity	0.46**	0.71**	0.53**	0.57**	0.77**	0.67**	1					
8. Pod Filling Period	-0.32*	0.24NS	0.22NS	0.45**	0.62**	0.55**	0.7**	1				
9. Pods Plant $^{-1}$	0.29NS	0.14NS	0.39*	0.29NS	0.23NS	0.32*	0.41**	0.2NS	1			
10. Seeds Pod $^{-1}$	0.06NS	0.05NS	0.14NS	0.23NS	0.19NS	0.04NS	0.08NS	0.04NS	-0.11NS	1		
11. Total Biomass	-0.28NS	-0.29NS	0.22NS	0.05NS	0NS	0.2NS	0.13NS	0.35*	0.53**	-0.19NS	1	
12. Seed Yield	-0.65**	-0.59**	-0.53**	-0.42**	-0.34*	-0.26NS	-0.52**	-0.03NS	-0.05NS	-0.07NS	0.25NS	1
13. Hundred Seed Weight	-0.51**	-0.7**	-0.41**	-0.29NS	-0.59**	-0.58**	-0.72**	-0.34*	-0.46**	0.09NS	-0.25NS	0.53**

Appendix xi: Analysis of Variance of all Studied Characters of *Desi* Genotypes at Juja and Kabete

Source of Variations	Long rain Juja	Short Rain Juja	Long Rain Kabete	Short Rain Kabete	Long rain Juja	Short Rain Juja	Long Rain Kabete	Short Rain Kabete
	Days to 50 % flowering				Number of leaflet leaf at $^{-1}$ Podding			
Genotype (G)	**	**	**	**	**	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Plant canopy width				Pod Length			
Genotype (G)	**	**	**	**	**	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Plant Height				Number of Primary Branches Plant $^{-1}$			
Genotype (G)	**	**	**	**	**	**	NS	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Number of Secondary Branches Plant $^{-1}$				Days to 75 % Maturity			
Genotype (G)	**	**	*	**	NS	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Pod Filling Period				Number of Pods Plant $^{-1}$			
Genotype (G)	**	**	**	**	**	**	*	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Number of Seeds Pod $^{-1}$				Biomass Yield ha $^{-1}$			
Genotype (G)	**	**	**	**	**	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Seed Yield ha $^{-1}$				Hundred Seed Weight			
Genotype (G)	**	**	**	**	**	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			

Note: GEI - Genotype by environment interactions

Appendix xii: Analysis of Variance of all Studied Characters of *Kabuli* Genotypes at Juja and Kabete

Source of variations	Days to 50 % flowering				Number of leaflet leaf at $^{-1}$ Podding			
	Long rain Juja	Short Rain Juja	Long Rain Kabete	Short Rain Kabete	Long rain Juja	Short Rain Juja	Long Rain Kabete	Short Rain Kabete
Genotype (G)	**	**	**	**	**	**	*	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Plant canopy width				Pod Length			
Genotype (G)	**	**	**	**	**	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Plant Height				Number of Primary Branches Plant $^{-1}$			
Genotype (G)	*	**	**	**	**	**	*	**
Environment (E)	**	**	**	**	**	**	*	**
GEI	**				**			
	Number of Secondary Branches Plant $^{-1}$				Days to 75 % Maturity			
Genotype (G)	**	**	**	**	*	**	NS	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Pod Filling Period				Number of Pods Plant $^{-1}$			
Genotype (G)	**	**	**	**	**	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			
	Number of Seeds Pod $^{-1}$				Biomass Yield ha $^{-1}$			
Genotype (G)	NS	**	**	**	**	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	*				**			
	Seed Yield ha $^{-1}$				Hundred Seed Weight			
Genotype (G)	**	**	**	**	**	**	**	**
Environment (E)	**	**	**	**	**	**	**	**
GEI	**				**			

Note: GEI - Genotype by environment interactions