Agronomic Evaluation of Eight Genotypes of Hot Pepper (Capsicum Spp L.) in a Coastal Savanna Zone of Ghana

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Abstract
Local landrace varieties of pepper (*Capsicum* sp) often fail to meet the expectations of farmers with respect to fruit yield, while exotic breeds are unadapted to local conditions, with detrimental effects on local pepper production. The aim of the study was to assess the agronomic performance of eight (8) pepper genotypes, comprising 6 exotic and 2 local genotypes, under rain-fed conditions to identify those suitable for cultivation locally. The experiment was conducted between April and October 2011 at the research farm of the Biotechnology and Nuclear Agriculture Research Institute of the Ghana Atomic Energy Commission. The Randomized Complete Block Design (RCBD), with three replicates was used. Weed control was carried out manually with the aid of a hoe and a cutlass at 4 and 10 weeks after planting (WAP). One application of 15-15-15 NPK fertilizer was made at 2 WAP, using a rate of 200 kg ha^{-1}. No pesticides or fungicides were applied. Parameters measured include number of days to 50% flowering, height at first branching, total plant height at maturity, canopy spread at maturity and total yield. Results indicate that exotic hybrid varieties matured earlier than the local genotypes. They also performed better in terms of fruit weight, fruit length and fruit yield. However, the two local landrace varieties, Anloga and Legon 18, produced the highest number of undamaged fruits.
Keywords: *Capsicum* sp, genotypes, exotic pepper, landrace, yield, plant height, fruit weight

1. Introduction

Pepper (*Capsicum sp.*), also widely known as chilli, is an important crop consumed all over the world and belongs to the family Solanaceae. It is believed to have originated from and domesticated in the Americas over 6,000 years ago. Though its fruits are considered to be vegetables, botanically they are berries. Pepper fruits are the most widely consumed as a spice. Though there are about 25-30 species of Capsicum, *Capsicum annuum* is the most widely cultivated species (Belletti et al., 1998, Csilléry, 2006, Ravishankar et al., 2003).

In Ghana, pepper is an inevitable constituent in the diets of many people. The nutritive value of the crop is high; it is an excellent source of vitamins A, B-complex, C (ascorbic acid), and E along with minerals like molybdenum, manganese, folate, potassium and thiamine. Some pepper varieties have been noted to contain seven times more vitamin C than orange (Lee and Kader, 2000). Beta-carotenoids, and vitamins A and C in pepper are powerful antioxidants that destroy free radicals (Simonne et al., 1997).

The crop is cultivated for its fruits which are used locally or exported to destinations in Europe. Currently, cultivation is on the decline as a result of incidence of pest and disease conditions, inadequate use of fertilisers, inadequate irrigation facilities, lack of an organized system for vegetable processing and marketing and the low income derived by farmers during the regular growing seasons (Anon, 2012; Millennium Development Authority, 2010). The absence of a viable seed industry for vegetable crops (including pepper) has paved the way for the unrestricted importation of exotic seed by local seed companies to fill the gap.

Consequently, farmers have access to both landraces as well as exotic varieties for commercial production of pepper. The local landraces are drought tolerant, and have long maturity periods but are inherently low yielding with long maturity periods. The exotic varieties are unadapted to local growing conditions and easily succumb to the vagaries of the weather and other abiotic and biotic determinants of yield thereby performing way below expectation. In the absence of current and reliable agronomic data on the performances of both local and exotic genotypes, farmers are likely to continue cultivating cultivars/genotypes with low economic potential.

This study was, thus, conducted to evaluate six exotic pepper genotypes against two local checks in order to identify superior genotypes with desirable growth and yield characteristics under prevailing field conditions. The outcome of this study should provide plant breeders with the information necessary for breeding of new varieties.

2. Method

2.1 *Area of Study*

The study was conducted at the Biotechnology and Nuclear Agriculture Research Institute of the Ghana Atomic Energy Commission between April and October 2011. The study site was located about 20 km north of Accra (05º 40' 60 N and 0º 13' 0 W), with an elevation of 76 m above sea level. The vegetation is Coastal Savannah, and the area is characterized by a bimodal rainfall pattern with the major season falling between the months of March and June, and a minor rainy season around October/November each year. The mean annual rainfall is 810 mm distributed over less than 80 days, and temperatures are moderate with maximum rarely exceeding 32 ºC while the minimum does not fall below 17 ºC.

2.2 *Experimental Material*

Six exotic and two indigenous genotypes were used for the study. The choice of materials was based on their widespread cultivation and economic importance. Descriptions of the genotypes used are shown in Table 1 and Figure 1.

2.3 Layout of experiment

Approximately one hundred and fifty (150) seeds of each genotype were sown in a nursery cell tray filled with a well-mixed substrate of 3:1:1 top soil, cow dung and coconut fibre respectively under a screen house. The nursery was watered thoroughly pre-and post-seed germination to facilitate seedling establishment. Green house grade Polyfeed (19:19:19 NPK), at a rate of 40 g per 13 litres of water, was applied to the roots to enhance active root formation and shoot growth. After 7 days of hardening, following 4 weeks of nursing, seedlings were transplanted to the field. Initial land preparation prior to transplanting included de-stumping, ploughing and harrowing. There were 30 plants per plot with each plot measuring 4.8 m x 3.0 m. The eight plots within a block were separated by a distance of 1.2 m. The Randomized Complete Block Design was used with three replications at 2 m apart, giving a total plot size of 36 m x 10.8 m. Weed control was carried out manually with the aid of a hoe and a cutlass at 4 and 10 weeks after planting (WAP). NPK (15: 15: 15) fertilizer was applied single dose at 2 WAP at a rate of 200 kg ha^{-1} but no pesticides or insecticides were applied.

2.4 Data collection

Vegetative traits: Ten plants were randomly selected and tagged for data collection in each plot. Data collected on vegetative traits include: days to 50% flowering, plant height at first branching, maturity and canopy spread at maturity. Days to 50% flowering was determined by recording the number of days following transplanting (DAT) until 50% of plants in a plot had at least one open flower. Height at first branching, plant height at maturity (4 MAP) and canopy spread were measured with the aid of a metre rule.

Fruit quality traits: Quality traits measured include fruit length, fruit width, fruit weight, flesh thickness. These were achieved by sampling 10 green matured and 10 ripe fruits per plant and five plants from each plot. Fruit diameter and flesh thickness was measured with the aid of a pair of Vernier callipers.

Yield traits: Yield traits were measured on fresh weight basis. Mature ripe fruits were harvested twice weekly till 3 months after fruiting. Damaged fruits included those fruits that were pierced by insects or rotten at any point. Parameters measured include number of damaged and undamaged fruits per plant number of seeds per fruit, total yield of damaged and undamaged fruit per hectare and total fruit yield per hectare.

2.5 Data analysis

Means of data collected were subjected to statistical analysis using one-way analysis of variance (ANOVA) and separated by the Duncan's multiple range test [Statgraphics (2010) Centurion XVI, version 16.1.11, USA], where found to be statistically different. A p-value of 0.05 or less was considered as statistically significant. Microsoft Office Excel was used in plotting of graphs.

3. Results and Discussion

3.1 Days to 50% flowering

Fig. 2 shows variation in the number of days to 50% flowering in the genotypes studied. Significant differences existed in days to 50% flowering among the genotypes studied. Forever F_1 was the first genotype to achieve 50% flowering at 18 DAT, which was not statistically different from the number of days taken by Sunny F_1 (21 DAT). Hence, both hybrids exhibited early maturity. Big Sun recorded the longest number of days to 50% flowering, at 41 DAT. This was not significantly different from number of days taken by Bombadier, Anloga, Antillas and Archard, but differed from days taken by Legon 18, Forever F_1 and Sunny F_1. Nkansah et al. (2011) reported values of 23-30 DAT for bird's eye pepper to achieve 50% flowering. Other workers reported values ranging 40-45 DAT (Roberts and Hope, 2004), 54-57 DAT (Mochiah et al., 2012), 56-62 DAT (Bozokalfa et al., 2009), 60-74 DAT (Valadez-Bustos et al., 2009), 61-83 DAT (Law-Ogbomo and Law-Ogbomo, 2010), and 68-75 DAT (Iqbal et al., 2009) for various genotypes of pepper to achieve 50% flowering.

The maturity period of a crop is a very important factor considered in the choice of planting material (Dewitt and Rosaland, 2009). Farmers in regions/districts/areas with short rainy periods prefer early-maturing varieties to avoid crop loss.

3.2 Height at First Branching

There was significant variation among genotypes for height at first branching as shown in Fig. 3. Archard branched at a height of 20 cm which was significantly shorter than the height at which all other genotypes branched. Anloga recorded the greatest height at first branching (30 cm) which was not statistically different from the height at which Sunny F1, Forever1 and Legon 18 achieved first branching. Height at first branching has a direct bearing on canopy height and the tendency of branches in the lower canopy to droop. Under high bearing, fruits from such canopies may touch the soil, predisposing them to infection from soil microorganisms thereby reducing quality of harvest (Ahmad et al., 2013; Barth et al., 2009; Belakbir et al., 1998; Snowden, 1980).

3.3 Plant height at maturity

Among all the genotypes studied, Big Sun recorded the highest plant height at maturity of 81.0 cm while Bombardier recorded the least (52.7 cm). Differences among genotypes for plant height at maturity were statistically significant (Fig 3). These results are consistent with the reports by other workers (Bozokalfa et al., 2009; Lahbib et al., 2013; Iqbal et al., 2009; Roberts and Hope, 2004). On the other hand, other reports indicate average plant height at maturity in the ranges of 16.6-57.6 cm (Nsabiyera et al., 2012), 23.8-25.02 cm (Mochiah et al., 2012), 32.1-68.3 cm (Nkansah et al., 2011), 60-90 cm (Dewitt and Rosaland, 2009) and 72 -117 cm (Valadez-Bustos et al., 2009). Rudall (1994) stated that increase in plant height is accompanied by a corresponding increase in stem girth/thickness, boosting the plant's resistance against lodging. Genotypic differences may account for variation in plant height in this study as explained by Decoteau and Graham (1994).

3.4 Canopy width at maturity

Mean canopy width of the genotypes is shown in Fig. 5. Canopy width varied from 66.95 cm in Sunny F1 to 101.68 cm in Archard. Differences in canopy width among genotypes were statistically significant. Canopy width varies among pepper genotypes as reported by Bozokalfa et al. (2009) and Roberts and Hope (2004). Nkansah et al. (2011) reported canopy width values of 30.2 -83.3 cm among bird's eye pepper genotypes. The findings in this study are inconsistent with those of Nsabiyera et al. (2012) who reported average canopy width of 35 genotypes of pepper in Uganda to vary from 10.8 - 61.7 cm.

Differences in canopy width among pepper varieties are most often associated with differences in varieties/genotypes, nutrition, soil moisture availability, age of seedlings at transplanting and planting distances (Decoteau and Graham, 1994; Nsabiyera et al. 2012). Usually plants with small canopy width make up for this deficiency with upright growth. Large canopy width provides large leaf area surfaces which enhance the interception of solar radiation with subsequent increase in the amount of photosynthetic activities, which correspondingly increases the plants assimilatory ability (Orak and llker, 2004).

3.5 Fruit Weight (unripe and red) among genotypes

Mean fruit weight of harvested samples (unripe and red) is shown in Fig. 6. Legon 18 recorded the least fruit weights of 6.94 g and 6.43g, while Forever F_1 recorded the highest (of 19.99 g and 19.56g) in the unripe and ripe states respectively. These were not significantly different from values recorded for Big Sun, Antillas and Archard. However, values recorded for Anloga, Bombardier, Sunny F_1 and Legon 18 were significantly lower at both the unripe and ripe state. In general, mean fruit weight of genotypes reduced from the green maturity state to the ripe state, except for the genotypes Anloga and Big Sun. For instance mean fruit weights of Antillas and Bombadier significantly reduced from 16.4 g to14.8 g, 10.1g to 8.8 g and 44.6 g to 41.8 g respectively. For all genotypes, differences in mean fruit weight among the green matured and ripe fruits were statistically highly significant ($p<0.001$). Similar results have been reported by other workers (Bozokalfa et al., 2009; Roberts and Hope, 2004). However, results reported in this study are higher than those reported by Tesfaw et al. (2013) and Nsabiyera et al. (2012).

3.6 Fruit diameter (unripe and red) among genotypes

Variation in mean fruit diameter of the pepper genotypes is shown in Fig. 7. Fruit diameter varied from 1.01 cm (Sunny F_1) to 4.15 cm (Big Sun) in matured green fruits. Similarly, in the ripe state, the same trend was observed with Sunny F_1 recording an average fruit diameter of 0.97 cm while Big Sun recorded an average fruit diameter of 4.10 cm. With the exception of Forever F_1, all other genotypes recorded a reduction in fruit diameter in the ripe and unripe state. Highly significant differences in fruit diameter existed among the genotypes in both the unripe and ripe fruits. Many earlier workers (Nsabiyera et al., 2012; Nkansah et al., 2011; Sezen et al., 2011), using different species of pepper, observed variation in mean fruit diameter. Hence, the variation in this trait appears to be in response to genotypic differences but may also be influenced by the factors which also affect canopy width (Decoteau and Graham, 1994; Nsabiyera et al. 2012).

3.7 Fruit Length (Unripe and ripe) among genotypes

Differences in mean fruit length among the genotypes are shown in Fig. 8. Antillas recorded the shortest fruit length, of 4.6 cm and 4.9 cm in the unripe and ripe fruits respectively, while Forever F_1, which recorded 15.8 cm and 16.6 cm for fruit length in the unripe and ripe states respectively, had the longest fruits. With the exception of Archard and Bombadier, all other genotypes recorded an increase in fruit length from the unripe to the ripe state. Highly significant differences existed among genotypes for mean fruit length in both unripe and ripe states. Fruit length is an important parameter in determining pepper fruit quality, especially for export (Nsabiyera et al., 2012). Forever F_1 and Sunny F_1, both hybrids, had the longest fruits. The results are consistent with those obtained by other researchers (Idowu-Agida et al., 2010; Sermenli and Mavi, 2010; AVRDC, 2004; Akinci and Akinci, 2004).

3.8 Flesh Thickness (Unripe and ripe) among genotypes

Mean flesh thickness of fruits at the unripe and ripe states of the genotypes is shown in Fig. 9. Sunny F_1, with values of 0.14 cm and 0.12 cm in the unripe and ripe fruits respectively, recorded the least flesh thickness among the genotypes while Forever F_1, with values of 0.20 cm and 0.18 cm, had the thickest fruits. There were significant differences in flesh thickness among genotypes in both unripe and ripe states. Values reported in this study are consistent with those reported by Nkansah et al. (2011), but conflict with those reported by Bozokalfa et al. (2009) and Lahbib et al. (2013). In all genotypes, except Legon 18, flesh thickness reduced with ripening.
Flesh thickness plays an important role in the processing of pepper. In Ghana, where most of the fruits of pepper are processed by sun-drying, thick-fleshed fruits require longer drying periods which may predispose them to fungal infection under sub-optimal conditions of humidity and temperature. On the other hand, pepper fruits with thin flesh are tender and liable to damage during post-harvest handling, thereby reducing their quality as fresh produce for export destinations.

3.9 Number of Seeds per fruit among genotypes

Fig. 10 shows differences in mean number of seeds per fruit among genotypes, ranging from 62 in Bombadier to 153 in Forever F_1. No significant differences were observed in mean number of seeds among Archard, Sunny F_1, Antillas, Legon 18, Big Sun and Bombardier. Mean number of seeds per fruit recorded in this study was consistent with the findings of Nsabiyera et al. (2012) and Akinci and Akinci (2004). Differences in mean number of seeds among pepper genotypes are mainly genetic, although stress related conditions such as drought and imbalanced soil pH can also affect seed number (Nsabiyera et al., 2012; Sezen et al., 2011)). For the food industry, low seeded fruits are preferred over heavily seeded fruits.

3.10 Total number of fruits per plant among genotypes

Fig. 11 shows variation in total number of fruits per plant among the eight genotypes of pepper studied, further categorization into damaged and undamaged fruits. Bombadier recorded the least number of undamaged fruits/plant (12.1) while Legon 18 produced the highest (81.57). Mean number of fruits/plant among genotypes was statistically significant for total number of fruits per plant as well as number of undamaged fruits per plant but not for the damaged. For damaged fruits, Anloga recorded the least number with a mean of 11.07, while Archard recorded the highest (27.03). Total number of fruits per plant was statistically significant among genotypes and highest in Legon 18 (94.63) and least in Big Sun (24.97). This is similar to the report of Nsabiyera et al. (2012) who recorded mean fruit numbers in the range 12-91 for some accessions of hot pepper, but contrasts with that of Nkansah et al. (2011) who reported values of 143-456. Fruit number is usually influenced by both genotypic and environmental conditions (Sezen et al., 2011).

Archard, which branched early and exhibited a prostrate growth habit, recorded the highest number of damaged fruits resulting from contact with the soil. Forever F_1, which recorded the heaviest fruit weight, also recorded a high number of damaged fruits. Heavy load of fruits caused the branches to droop, with fruits in the lower canopy touching the soil and thereby predisposing them to soil–borne pathogens (Fig. 12).

3.11 Total fruit yield per hectare among genotypes

Variation in total fruit yield per hectare among genotypes, extrapolated from yield per plot, is presented in Fig.

13. This is further partitioned into damaged and undamaged fruit yield per hectare. Forever F_1 however recorded the highest total fruit yield of 9.53 t ha^{-1} while Bombadier recorded the least with 3.05 ton/ha. Differences in total yield among the genotypes are statistically significant. Damaged fruit yield ranged from 0.84 t ha^{-1} in Legon 18 to 5.32 t ha^{-1} in Forever F_1. Differences in yield of damaged fruit per hectare among genotypes were also statistically significant. Undamaged fruit yield per hectare ranged from 1.49 t ha^{-1} to 6.8 t ha^{-1} in Bombardier and Anloga respectively with significant differences among genotypes. Among all genotypes only Forever F_1 recorded more damaged fruits than undamaged fruits. Significant differences existed in yield of damaged fruits among the genotypes. Working with 35 genotypes of hot pepper, Nsabiyera et al. (2012) reported total fruit yield in the range 1.0-17.9 t ha^{-1}. Nkansah et al. (2011) recorded values between 10.4-39.3 t ha^{-1}. Sezen et al. (2011) also reported fruit yield of 21.39-35.92 t ha-1 in cayenne pepper. In Taiwan, Jordan and Tanzania, total fruit yield of pepper has been reported to vary from 5.64-35.25 t ha^{-1}, , 8.5-27.2 t ha^{-1} and 10.06-38.46 t ha^{-1}respectively (AVRDC, 2004), indicating that results from the current study compare poorly with those reported from these other regions. Anloga, a farmers' variety (landrace), recorded the highest undamaged fruit yield per hectare, reflecting its superior adaptation to local conditions compared to the other genotypes.

4. Conclusion

The exotic pepper genotypes out-performed the local genotypes with reference to days to 50% flowering, fruit length, fruit weight, fruit diameter, flesh thickness and total fruit yield but recorded higher number of damaged fruits. Two local landraces, Legon 18 and Anloga, recorded the highest number of undamaged fruits per plant and per hectare respectively. The two may be used in future breeding work.

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Table 1. Description of pepper genotypes used in the study

Genotype	ID	Botanical classification	Source	Status	Pungency	Colour at ripening
Archard	Arch.	*Capsicum annuum* L.	Agriseed Co. Ltd.	Exotic	Mild to hot	Red
Sunny F_1	Sun.	*Capsicum frutescens* L.	Agriseed Co. Ltd.	Exotic	Hot	Red
Forever F_1	For.	*Capsicum frutescens* L.	Agriseed Co. Ltd.	Exotic	Hot	Red
Legon 28	Leg.	*Capsicum frutescens* L.	Agrimat Co. Ltd	Local check	Hot	Red
Anloga	Anlo.	*Capsicum frutescens* L.	Farmer's field	Farmer's variety	Hot	Red
Big Sun	Big S.	*Capsicum chinense* L.	Agriseed Co. Ltd.	Exotic	Hot	Yellow
Bombadier	Bomb.	*Capsicum chinense* L.	Agriseed Co. Ltd.	Exotic	Hot	Red
Antillas	Anti.	*Capsicum chinense* L.	Agriseed Co. Ltd.	Exotic	Hot	Red

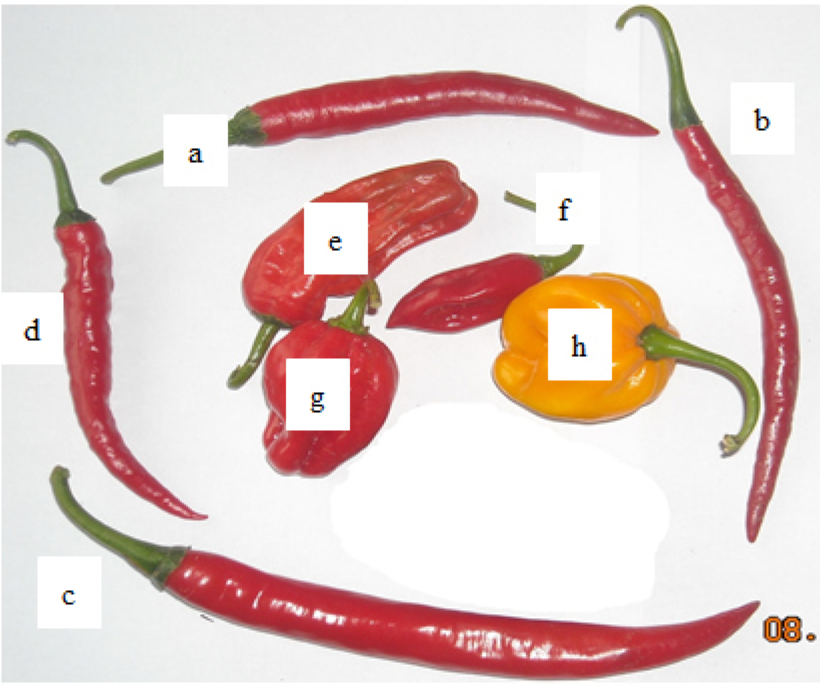


Figure 1. Ripe fruits of pepper genotypes used in the study: (a) Anloga, (b) Sunny F_1, (c) Forever F_1, (d) Legon 18, (e) Archard, (f) Bombadier, (g) Antillas and (h) Big Sun.

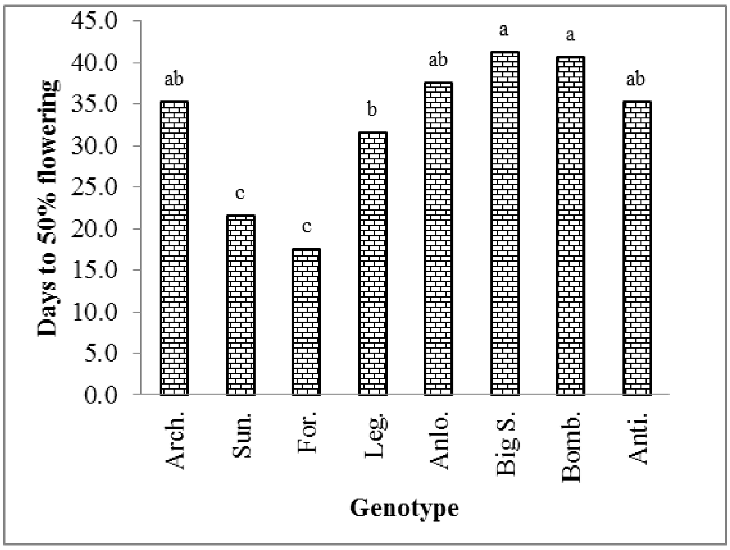


Figure 2. Days to 50% flowering among genotypes

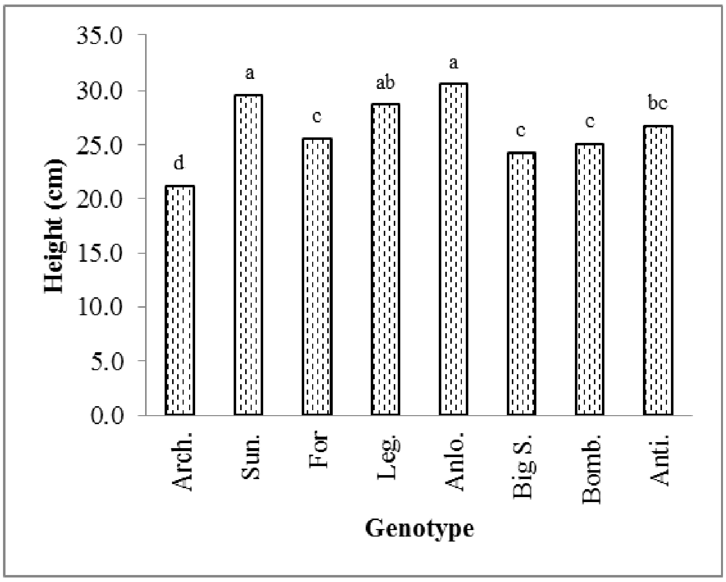


Figure 3. Height at first branching among genotypes

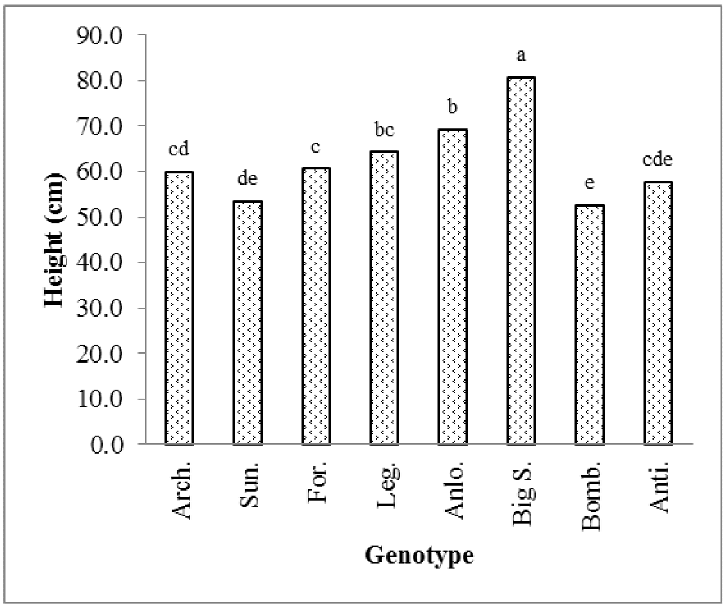


Figure 4. Plant height at maturity among genotypes

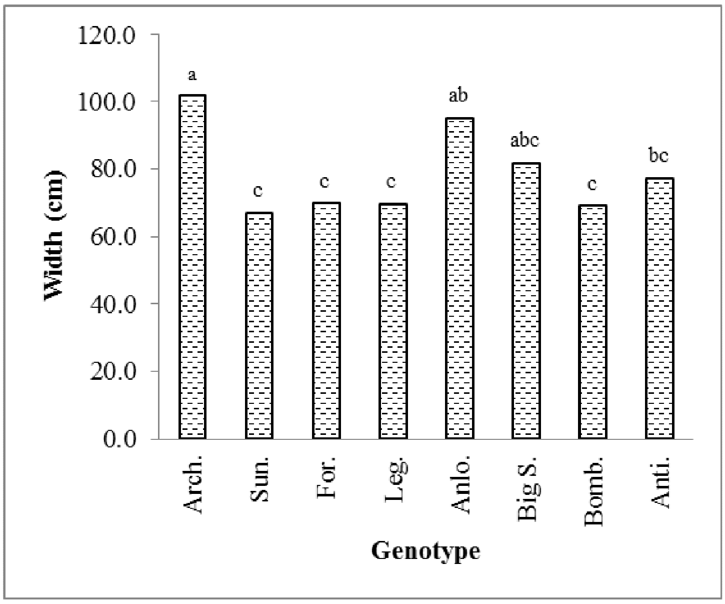


Figure 5. Canopy width at maturity among genotypes

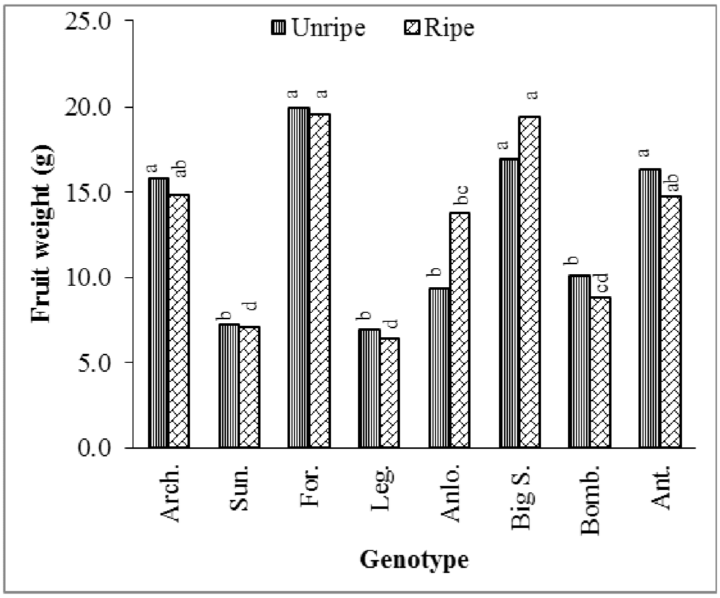


Figure 6. Fruit weight (g) of the genotypes

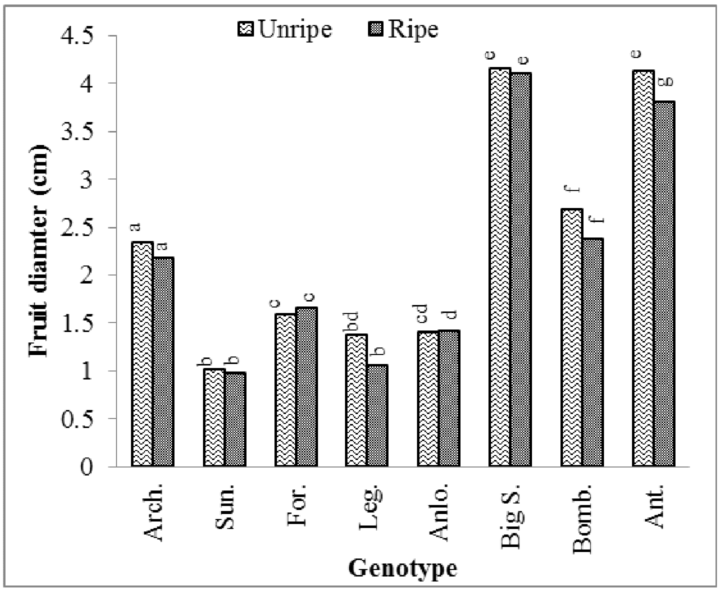
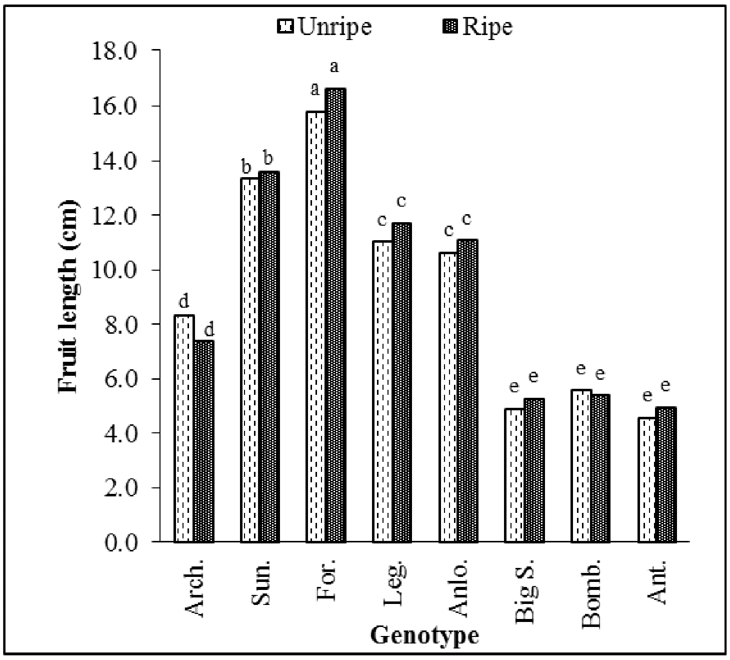


Figure 7. Fruit diameter (cm) of the genotypes



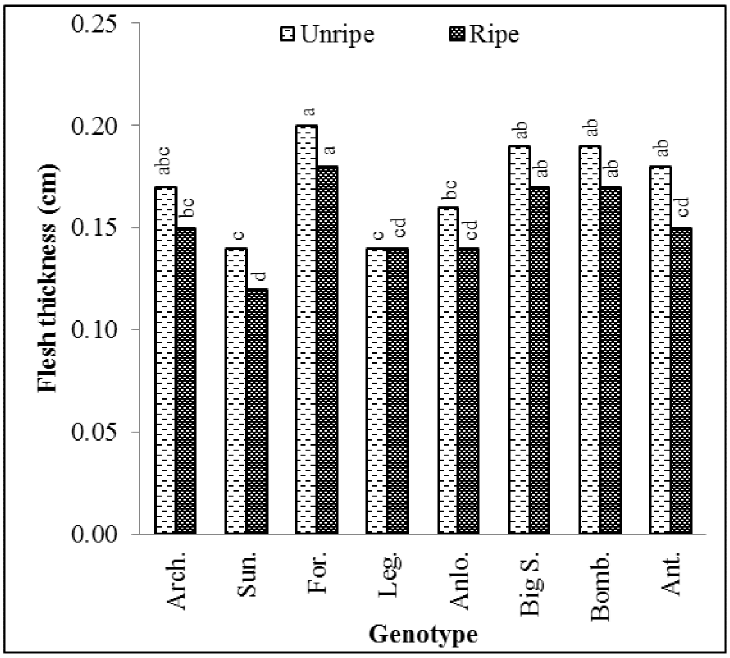


Figure 9. Flesh thickness (cm) of the pepper genotypes

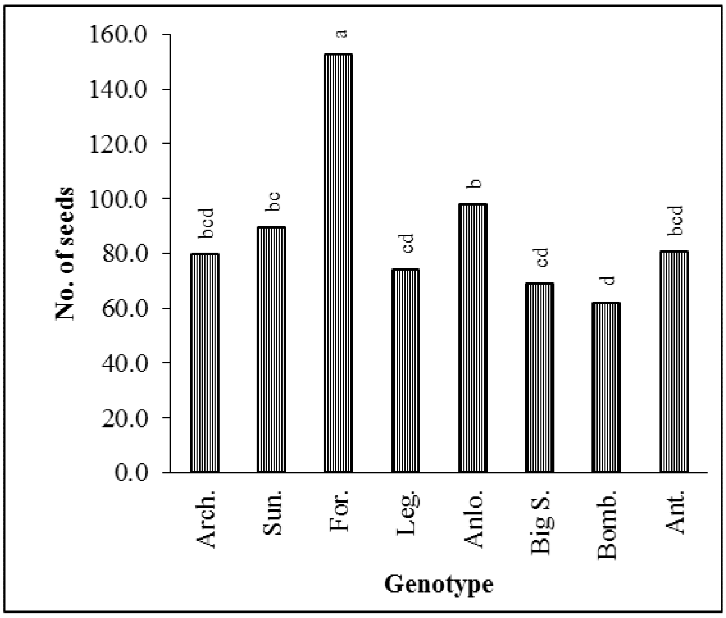


Figure 10. Number of Seeds/per fruit among genotypes

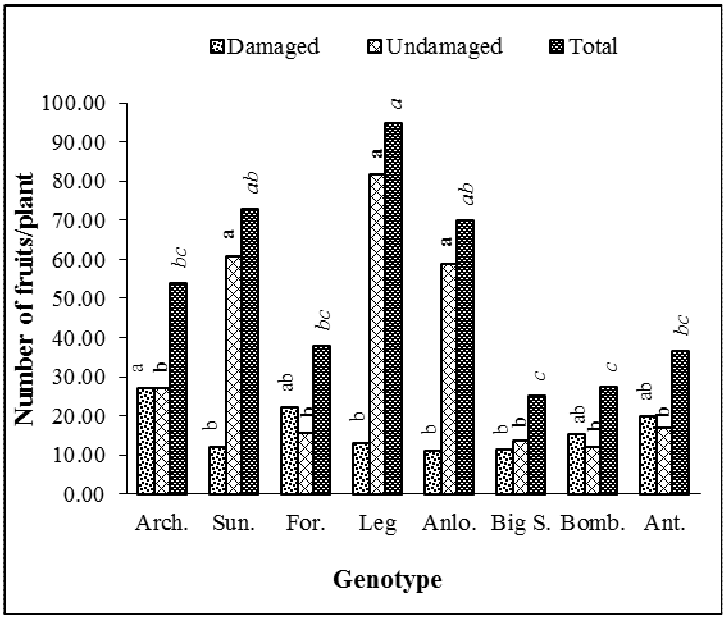


Figure 11. Number of fruits/plant among genotypes

Figure 12. Fruits of Forever F_1 showing extent of damage

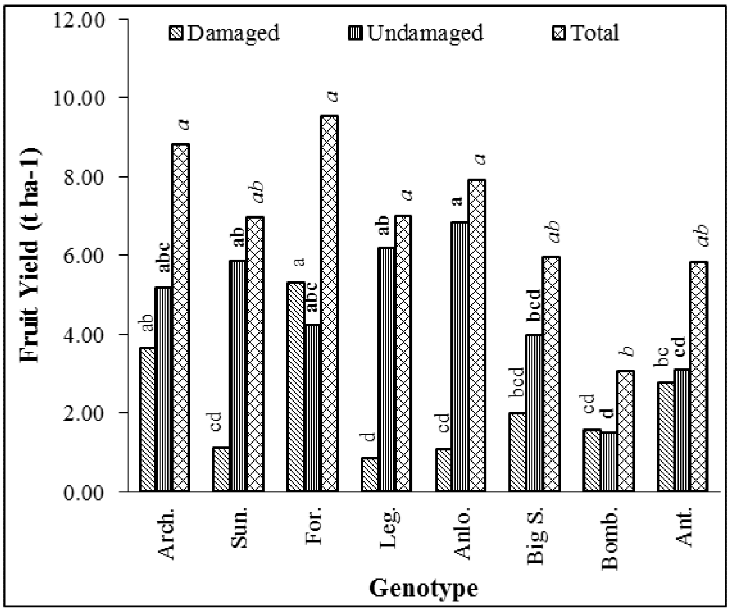


Figure 13. Yield of pepper genotypes in t ha^{-1}

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