AGRONOMIC PERFORMANCE OF THREE MOST POPULAR COMMERCIAL WATERMELON CULTIVARS IN KENYA AS COMPARED TO ONE NEWLY INTRODUCED CULTIVAR AND ONE LOCAL LANDRACE GROWN ON DYSTRIC NITISOLS UNDER SUB-HUMID TROPICAL CONDITIONS

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ABSTRACT

Agronomic performance trial involving five cultivated watermelon accessions available in Kenya was conducted at Maseno University Research Fields for two seasons between year 2007 and 2008. The accessions included three most common commercial watermelon cultivars in Kenya namely 'Sugarbaby', 'Crimson Sweet' and 'Charleston Gray'; one newly introduced cultivar from United States namely 'Yellow Crimson'; and one local landrace (GBK-043014) from Kaka mega district in Western Kenya. The five were evaluated on dystric nitisols under sub-humid conditions of Maseno Division, Nyanza Province in Kenya. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data was collected on agronomic characters including days to emergence, days to flowering, maturity period, and main vine length, number of branches on the main vine and fruit yield (number and weight). The data was subjected to analysis of variance (ANOVA) using SAS version 9.1 and differences declared significant at 5% level. Least Significant Difference ($LSD_{5\%}$) was used to separate the means. Linear correlation was done to compare the relationship between variables. Results demonstrated significant differences in agronomic performance between accessions. 'Yellow Crimson' was recommended to Kenyan growers as the best commercial cultivar with agronomic traits which leads to high yields. The landrace was found to contain various desirable agronomic traits which can be selected in future breeding programs. These include long main vine and extensive branching which were found to be highly correlated to yields. It is, however, highly seeded and its taste is unpleasant and should therefore be improved with regard to these traits.

Keywords: watermelon, commercial cultivars, agronomic performance, landrace, kenya.

INTRODUCTION

Watermelon (Citrullus lanatus) is one of the most widely cultivated crops in the world (Huh *et al*., 2008). Its global consumption is greater than that of any other cucurbit. It accounts for 6.8% of the world area devoted to vegetable production (Guner and Wehner, 2004; Goreta *et al*., 2005). China is the leading country in production of watermelon followed by Turkey, United States, Iran and Republic of Korea (Huh *et al*., 2008; Wehner and Maynard, 2003). There are over 1,200 varieties of watermelon worldwide (Miles, 2004) and a wide variety of watermelons have been cultivated in Africa (Zohary and Hopf, 2000). Several of these varieties have been recommended for Kenyan range of climate.

These include Sugarbaby Crimson Sweet 'Charleston Gray Chilean Black Congo Fairfax and 'Tom Watson' (Tindall, 1983). However, among these seven cultivars, only the first three are available in Kenyan markets with 'Sugarbaby' being the most popular (HCDA, 2004). This makes demand of watermelon in Kenya to be higher than production resulting in the fruit being very expensive and only affordable to rich people. With local demand unsatisfied, its potential for export can not be realized. To meet the local demand and may be create some surplus for export, production of watermelon in Kenya obviously needs to be increased (HCDA, 2006).

There is an ongoing need for watermelon improvement, for increased disease and pest resistance and also for fruit qualities to better meet market demands (Levi *et al*., 2001a). This must be done considering consumer preferences, yield potential, desired earliness, fruit size and shape, disease and pest resistance among others. Watermelons are susceptible to several diseases that attack the roots, foliage, and fruit resulting in reduced yields. These include Fusarium wilt, anthracnose, damping off, gummy stem blight, bacterial fruit blotch, yellow vine, bacterial rind necrosis, cercospora leaf spot, angular leaf spot, alternaria leaf spot, Phytophthora blight, powdery mildew, downey mildew and viral diseases (Roberts and Kucharek, 2006; Sikora, 1997).

Disease control is essential in the production of high quality watermelons. A control program that combines the use of cultural practices, genetic resistance, and chemical application as needed usually provides the best results. The use of disease-resistant varieties is an economical means of controlling diseases (Warren *et al*., 1990). Owing to their different genetic composition, different varieties of watermelon will respond differently to various stresses. In order to come up with the best variety for a given agro-ecological zone, it is essential to conduct a performance trial with common varieties in that area and including some additional varieties to test for

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more desirable traits and to introduce new varieties (Marr and Tisserat, 1998).

Although many watermelon cultivars have been developed throughout the world during the last century, there is little information regarding their ancestries (Levi *et al*., 2001b). In Kenya, for example, some watermelon landraces have been identified in different parts of the country but there is scant data available comparing them with the modern cultivars. The factors which result in farmers preferring local landraces over modern varieties are not therefore very well understood.

The available information suggests that modern varieties often lack additional characters which farmers consider important (Hardon and Boef, 1993). There is therefore need to evaluate the agronomic performance of various watermelon accessions in Kenya in order to generate comparative data for local crop development. This data will be essential to validate suggested comparative advantages of landraces over modern cultivars or vice versa, and may provide new options for plant breeding. The objective of this study was to compare the agronomic performance and yield potential of the three most popular commercial watermelon cultivars in Kenya with one newly introduced cultivar and one local landrace.

MATERIALS AND METHODS

This study was carried out at Maseno University Research fields. The site lies along Kisumu-Busia highway in Maseno Division, Nyanza Province, Kenya within the upper Midland 1 agro-ecological zone (Jaetzold and Schimidt, 1982). Maseno lies at latitude 0^o 1’N-$0^0$12’S and longitude 34^o25’E-47’E and it is approximately 1500m above the sea level. The area receives a bimodal mean annual rainfall of 1750mm (Mwai *et al.*, 2001) with the first rainy season falling between March and July; and second season falling between September and early December. No month, however, is completely dry (Jaetzold and Schimidt, 1982). The mean annual temperature is 28.7^{o}C (Mwai *et al.*, 2001) with the hottest season occurring between January and April (Jaetzold and Schimidt, 1982).

The soils are classified as dystric nitisols. They are well-drained, deep reddish brown, slightly friable clay with pH ranging between 4.5 and 5.4. Soil organic carbon and phosphorous content are 1.8% and 4.5mg/kg respectively (Mwai *et al*., 2001).

Five cultivated watermelon in Kenya were used in this study. These included ‘Sugarbaby’, ‘Charleston Grey’, and ‘Crimson Sweet’, which are the most popular commercial cultivars in Kenya; ‘Yellow Crimson’ which is a newly introduced commercial cultivar from United States; and one landrace (GBK-043014) from Kaka mega district (altitude 1250-1500m ASL) in Western Kenya. Seeds of the landrace were obtained from National Genebank of Kenya (Muguga) in March 2007 and were grown at Maseno University Horticultural Fields for seed bulking before proceeding to the main study. Commercial cultivars were obtained from local shops except ‘Yellow Crimson’ which was obtained from Rispern Seeds, INC. Beecher, Illinois. ‘Sugarbaby’, ‘Charleston Grey’ and ‘Crimson Sweet’ were from East Africa Seeds, Kenya. ‘Yellow Crimson’ was included in the study because it has also been noted in some local supermarkets although the seed is not readily available in seed shops here in Kenya.

The seeds were directly sown in the field at a spacing of 1.5m x 1.5m. Since watermelon is reported to have poor germination, five to ten seeds were planted per hole but were thinned to one seedling three-four weeks after planting. Organic manure and NPK fertilizer were applied in the planting holes before sowing at the recommended rate of thirty (30) t/ha and 200 Kg/ha, respectively. Two rows of ‘sugarbaby’ were used as guard rows around the experimental field. Other agronomic practices including irrigation, weeding and top dressing were conducted uniformly and as required in all plots. No chemicals or any other method of pest and disease control were employed.

The first season experiment was conducted between September and December, 2007 followed by the second season experiment between January and May, 2008. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

Data was collected on agronomic characters such as days to emergence, days to flowering, days to maturity, main vine length, number of branches on the main vine and fruit yield (number and weight). The data was subjected to analysis of variance (ANOVA) using SAS version 9.1 (SAS Institute, 2005) and differences declared significant at 5% level. Least Significant Difference ($LSD_{5\%}$) was used to separate the means. Linear correlation was done to compare the relationship between variables. Descriptive statistics (mean, standard deviation, and coefficient of variation), were generated using the SAS procedure, UNIVARIATE.

RESULTS

Highly significant ($p<0.001$) variation in various quantitative agronomic characters were observed between the five watermelon accessions as shown in Table-1. For days to emergence, ‘Crimson Sweet’ and ‘Charleston Gray’ recorded the shortest time (6 and 7 days respectively) and were not significantly ($p>0.05$) different from each other. Kaka mega landrace, ‘Yellow Crimson’ and ‘Sugarbaby’ germinated after 13, 11 and 9 days, respectively and were all significantly ($p<0.05$) different from each other.

All commercial cultivars, however, portrayed non-uniform germination in both seasons with some seeds germinating even a month after sowing.

Flowering was found to start from the sixth week after planting and the first flower to open was always a male flower. ‘Sugarbaby’ took significantly ($p<0.05$) the shortest time (45 days) to first male flower while Kaka mega landrace took significantly ($p<0.05$) the longest time (63 days) to first male flower. ‘Crimson Sweet’, ‘Yellow Crimson’ and ‘Charleston Grey’ took 55, 58 and 59 days, respectively. The opening of the first female flower occurred 6-13 days after the opening of the first male flower. ‘Sugarbaby’ recorded significantly ($p<0.05$) the shortest time to anthesis of its first female flower (51 days)

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while the Kaka mega landrace recorded significantly the longest time (74 days). 'Yellow Crimson' recorded 66 days while 'Charleston Gray' and 'Crimson Sweet' took 68 days to open their first female flower.

Maturity period was also highly variable with the landrace taking the longest time (135 days). 'Sugarbaby' took the shortest time to mature (101 days) followed by 'Yellow Crimson' (105 days). 'Charleston Gray' and 'Crimson Sweet' matured in 111 and 113 days, respectively and were not significantly ($p>0.05$) different from each other. There was a strong ($R = 0.78$, $R^2 = 0.608$) and highly significant ($p<0.001$) positive correlation between the number of days to maturity and the number of days to the opening of the first female flower as shown in Figure-1(a).

Other agronomic characters that were evaluated include length of the main vine, number of branches on the main vine, fruit number and fruit yield. Kakamega landrace had significantly ($p<0.05$) the longest main vine (448cm) which was also the most branched (11 branches). On the other hand, 'Crimson Sweet' had significantly ($p < 0.05$) the shortest main vine (201cm) which was also the least branched (5 branches). 'Sugarbaby', 'Charleston Gray', and 'Yellow Crimson' recorded main vine length of 228cm with 7 branches, 233cm with 7 branches, and 244cm with 9 branches, respectively.

All accessions were significantly ($p<0.05$) different in number of fruits per plant. The Kaka mega landrace emerged significantly the best yielder with 5.67 fruits/plant (1814 fruits/ha) but its fruits were lighter in weight (averaging 1.99 kg) compared to those of 'Yellow Crimson' which averaged 3.01 kg. 'Yellow Crimson' produced an average of 3.45 fruits/plant (1104 fruits/ha). 'Sugarbaby' recorded an average fruit yield of 2.39 fruits/plant (765 fruits/ha) averaging 2.05 kg in weight while 'Charleston Gray' produced an average of 1.5 fruits/plant (480 fruits/ha) which averaged 1.77kg in weight. 'Crimson Sweet' recorded the lowest yields of 0.89 fruits/plant (285 fruits/ha) weighing 1.44kg on average. There was a strong and highly significant ($p<0.001$) positive correlation between fruit number and the two yield components i.e. main vine length ($R = 0.915$, $R^2 = 0.84$) and branch number ($R = 0.98$, $R^2 = 0.96$) as shown in Figure-1(b).

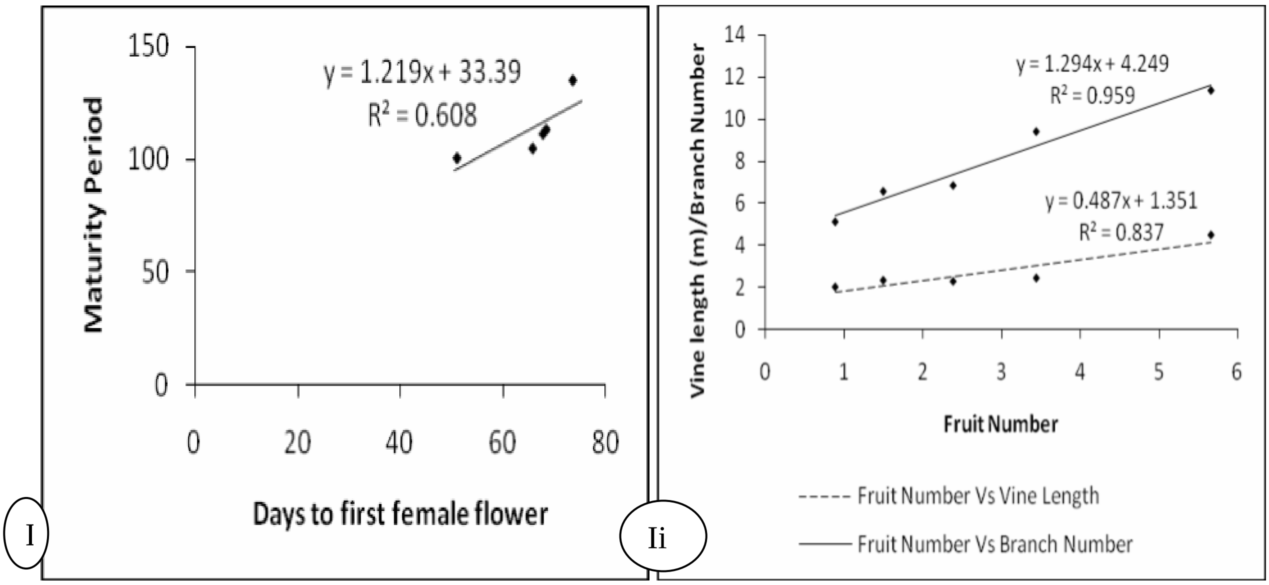

Figure-1. (a): Linear correlation between maturity period and days to first female flower.
(b): Linear correlation between fruit number and main yield components.

DISCUSSIONS

Evaluated accessions portrayed a wide range of variation in agronomic performance right from germination to fruit maturity. In general, the commercial cultivars took relatively shorter time to germinate compared to the landrace, except 'Yellow Crimson' whose emergence period compared well to that of the landrace. This delayed emergence exhibited by the landrace may be attributed to high levels of cucurbitacin. Cucurbitacin is a bitter substance produced by the Cucurbitaceae species. Unlike commercial cultivars, the landrace has not been selected for low cucurbitacin content.

This substance is reportedly antagonistic to gibberellins which are important in seed germination (Martin and Blackburn, 2003). Presence of high levels of cucurbitacin in the landrace was confirmed by its attractiveness to cucumber beetles (data not presented). Cucurbitacin acts as a stimulant to diabrotica beetles which may be attracted from a considerable distance to cucurbit plants with high cucurbitacin content (Robinson, 1992). Although 'Yellow Crimson' is an improved cultivar, it may also contain a considerable amount of cucurbitacin as it also portrayed delayed germination and was attractive to cucumber beetles. Other commercial cultivars germinated within the reported (Kovatch, 2003) range of 7-10 days (when soil temperature is in the optimum range of 21-30^{o}C). Poor and non-uniform germination that was observed among all commercial

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cultivars may be attributed to ploidy level. Joskani *et al*. (2005) indicated that polyploid watermelon often germinate poorly owing to the high protein content in the seeds. Also, polyploids generally suffer a high degree of infertility (Simmonds, 1979). Such germination problems could be one of the reasons discouraging many farmers from growing watermelon in Kenya.

Highly significant variation ($p<0.001$) in number of days to both first male and female flower opening was observed between accessions. These were attributed purely to genetic differences between the accessions as they were all exposed to same environmental conditions. According to Wehner *et al*. (2001), flowering in cucurbits normally starts in about 40-45 days after sowing depending upon the weather condition. Although Maseno is generally warm which is expected to enhance flowering, most accessions demonstrated delayed flowering which occurred between 45-63 days depending on accession.

The first flower in all the accessions was always a male flower which opened a few days to a few weeks earlier than the first female flower. Wehner *et al*. (2001) reported that the sequence of flowering follows a set pattern, namely; (i) Male phase: first few nodes bear only the staminate flowers, (ii) Mixed phase: both pistillate and staminate flowers appear in few nodes in the main axis and secondary branches in cycles and (iii) Female phase: few nodes produce mostly the pistillate flowers. Most accessions produced their first female flower in less than a fortnight after producing their first male flower.

The time taken to the opening of the first female flower was found to have a significant ($p<0.001$) and strong positive correlation ($R = 0.78$, $R^2 = 0.608$) to number of days to maturity [Figure-1(a)] suggesting that the start of pistillate flowering has a direct influence on maturity period in watermelon.

Commercial cultivars matured in a relatively shorter period compared to the landrace. This may be attributed to continued breeding and selection for earliness employed by breeders during the development of new cultivars.

For the landrace chances are that no such selection for earliness has been employed at all. Adelberg *et al*. (1997) reported that watermelon fruit matures in 80-110 days from sowing depending on the variety and growing conditions and that optimal growth occurs when day temperatures are in the range of 21-30^{0}C and night temperatures are ranging from 18-21^{0}C. Hall (2004) added that watermelon plants are among the most efficient in the higher plant kingdom for utilization of the natural environmental factors in growth and in metabolic processes and that under normal conditions, a single plant will grow, flower, set fruit and mature in 85-90 days from seeding. All accessions, therefore, took longer than usual to mature in both seasons probably due to unsuitable ecological conditions.

Highly significant ($p<0.001$) variation in length of the main vine was observed between accessions in both seasons. This concurs with the results of Dittmar *et al*. (2001) who also reported differences in vine vigor and growth among watermelon cultivars.

The landrace had significantly ($p<0.05$) the longest main vine as compared to cultivated accessions. This considerably long vine of the landrace along with its extensive branching could be one of the factors responsible for its relatively high yields.

Yellow Crimson', which is a newly bred cultivar had significantly ($p<0.05$) the longest main vine among the commercial cultivars while 'Crimson Sweet' had significantly ($p<0.05$) the shortest main vine. Main vine length, however, did not vary much amongst commercial cultivars as compared to the landrace whose vine length was more than double that of 'Crimson Sweet'. Warren *et al.* (1998) noted that watermelon vines if left undisturbed will normally attain a length of between 360 and 480cm.

The vine lengths of all inbred cultivars were therefore below average and this could have contributed largely to their low yields. Warren *et al.* (1998) reported that watermelon plants with longer vines also produce higher yields than those with shorter vines. This was confirmed by a strong ($R = 0.915$, $R^2 = 0.84$) and highly significant ($p<0.001$) positive correlation that was observed between main vine length and fruit number [Figure-1(b)].

The main vines of Kakamega landrace and 'Yellow Crimson' were significantly ($p<0.05$) the most branched with some of the branches even managing to produce sub-branches. However, the landrace was found to produce more sub-branches than 'Yellow Crimson' and its sub-branches also bore fruits thus resulting in higher yields.

The main branches of 'Yellow Crimson' produced very few sub-branches which hardly bore any fruits. This along with its long vine explains why the landrace ultimately produced more fruits than 'Yellow Crimson' even though the two accessions produced approximately equal number of branches from their main vines. 'Charleston Gray', 'Sugarbaby' and 'Crimson sweet' produced relatively fewer branches with considerably very few if any sub-branches which hardly produced any fruits hence their low yields. Warren *et al.* (1998) indicated that watermelon plants with many branches produce higher yields than those with few branches or those whose branches has been pruned.

This was confirmed by a strong ($R = 0.98$, $R^2 = 0.96$) and highly significant ($p<0.001$) positive correlation that was observed between branch number and fruit number [Figure-1(b)].

There was highly significant difference ($p<0.001$) between accessions in both fruit number and fruit weight. The Kakamega landrace yielded much better compared to commercial cultivars.

This landrace was apparently well adapted to climatic and edaphic conditions of Maseno, probably because of the close proximity between Maseno and Kakamega. It was, however, found to produce small-sized fruits and therefore, although it produced more fruits, its yield in kilograms was just slightly above that of 'Yellow Crimson' which emerged significantly ($p<0.05$) the best yielder among the commercial cultivars.

The high fruit yields of these two accessions were attributed to their relatively higher disease and pest resistance (data not presented), and their vigorous growth with more foliage, extensive branching and longer vine length.

They also produced more sub-branches than the rest of the accessions resulting in more foliage. Warren *et al*. (1998) indicated that more watermelon foliage translates into high photosynthetic and assimilation rates and ultimately to more fruits, and any reduction in foliage will reduce watermelon yields.

They added that watermelon plants with longer vines also produce higher yields than those with shorter vines. Since watermelon flowers develop in the nodes of the plants, additional branching on some watermelon accessions creates more locations for the flowers to be developed (Dittmar *et al*., 2001).

High yields of 'Yellow Crimson' may also be attributed to its tolerance to acidic soils and its wider geographic adaptability as reported by Anon. (2001). Development of new varieties with wide range of geographic adaptability that include soils, temperatures and moisture conditions is one of the primary goals of breeding (Hall, 2004).

The production of other commercial cultivars was below average; ranging from 1-2 fruits which were relatively small compared to 'Yellow Crimson'. McFarlane (2007) reported that watermelon fruits vary in weight from less than 4 to over 18kgs depending on the variety but none of the accessions in this study fell in this range.

This could have been caused by poor agro-ecological conditions that these accessions were exposed to including acidic soils of Maseno, as indicated by Mwai *et al*. (2001).

In addition, the low fruit yields of commercial cultivars as compared to the landrace may be attributed to their higher susceptibility to diseases and pests especially melon fly (data not presented).

CONCLUSIONS

The study was the first report comparing the three most popular commercial watermelon cultivars in Kenya with a newly introduced cultivar and one Kenyan landrace. The landrace emerged the best performer though it contained some undesirable traits such as poor taste and so many seeds.

This accession has not been selected for low cucurbitacin content and sweet taste. However, since it contains more desirable than undesirable agronomic traits, it should be improved for production especially in Western and Nyanza provinces of Kenya. Although 'Yellow Crimson' is a relatively new variety which is hardly known to many Kenyan watermelon growers, it was found to be the best performer among the commercial cultivars. Its good performance was attributed largely to its apparently wider geographic adaptation, which enabled it to grow more vigorously and ultimately resulting in high fruit yield.

The fruit was also very sweet and watery. It was therefore recommended for adoption by Kenyan growers and seed companies should make efforts of availing its seeds to growers. 'Sugarbaby', though being an old cultivar just like 'Charleston Gray' and 'Crimson Sweet' portrayed better performance than the latter two cultivars. It appeared to have a wider climatic adaptation and this could be the major reason why it is the most popular watermelon in Kenya and also in the world apart from its good and wider consumer acceptance (Johnson, 2007). If this cultivar can be improved for better disease and pest resistance, it still has great potential.

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Table-1. Variation in agronomic characters.

Accession	Days to emergence	DTMF	DTFF	DBMF	Days to maturity	Main vine length (cm)	Branch number	Fruit number	Fruit weight (kg)
Sugarbaby	8.83[c]	45.00[d]	51.06[c]	6.05[d]	100.67[d]	227.860[c]	6.83[c]	2.39[c]	2.05[b]
Yellow Crimson	11.44[b]	57.56[cb]	65.72[b]	8.11[c]	104.89[c]	243.56[b]	9.39[b]	3.45[b]	3.01[a]
Crimson Sweet	6.39[d]	55.44[c]	68.33[b]	12.89[a]	113.22[b]	200.555[d]	5.11[d]	0.89[e]	1.44[d]
Charleston Gray	6.61[d]	58.50[b]	67.72[b]	9.67[b]	111.36[b]	232.83[bc]	6.56[cd]	1.50[d]	1.77[c]
Landrace	12.89[a]	62.78[a]	73.50[a]	10.72[b]	134.83[a]	447.67[a]	11.33[a]	5.67[a]	1.99[bc]
$LSD_{5\%}$	0.7698	2.4067	2.6963	1.5236	3.6398	15.616	1.646	0.578	0.235
F Test	***	***	***	***	***	***	***	***	***
CV (%)	31.76	14.14	13.51	51.64	11.55	34.19	37.14	27.89	29.41
SD	2.9324	7.8968	8.8195	4.9000	13.0544	92.495	2.913	1.797	0.603

NB: Means followed by the same letter are not significantly different
*** = Highly Significant
DTMF = Days to opening of first male flower
DTFF = Days to opening of first female flower
DBMF = Days between male and female flower