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Full Length Research Paper

Yield quality of statice [*Limonium sinuatum* (L.) Mill.] as affected by cultivars and planting densities

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A study was conducted in a plastic greenhouse at Freesia Ethiopia PLC Sululta located in the central highlands of Ethiopia with the objective of determining the effect of cultivar, planting density and their interaction effect with reference to yield and quality of Statice. The experiment was laid out in a 3 x 4 factorial arrangement using a Randomized Complete Block Design (RCBD) with three replications. The treatments consisted of three cultivars ('Amazon Bird', 'Giant Blue Bird' and 'Yellow Sun Bird') and four different planting densities (4, 6, 8, and 10 plants per m^2). Data were collected on parameters pertaining to growth, yield and quality of Statice. The results of the study indicate a trend of rise in the number of marketable and unmarketable flowering stems per plot as the plant density increased from 4 to 10 plants per m^2. Conversely, flowers' vase life significantly (P<0.01) decreased when planted densely. In addition, the fresh weight of the marketable stems significantly (P<0.01) decreased as planting density increased. Among the cultivars, 'Yellow Sun Bird' was found to be more productive in terms of marketable stems followed by 'Giant Blue Bird' and 'Amazon'. In terms of stem length, 'Yellow Sun Bird' was found to be higher but was not statistically different from 'Giant Blue Bird'. With regards to vase life quality, the best result was obtained from 'Amazon Bird' cultivar. Overall, the study reveals that planting density and varietal differences had valid effects on the yield and quality of Statice. Cultivars 'Giant Blue Bird' and 'Yellow Sun Bird' had better performance in many of the parameters than the 'Amazon Bird' cultivar. The highest planting density (10 plants per m^2) demonstrated a positive influence on most of the evaluated parameters and therefore can be recommended for use by commercial growers in Ethiopia. However, further investigation is imperative on issues pertaining to the determination of nutrient supply for regulating the fresh weight of the product and other economic related topics.

Key words: Statice, *Limonium sinuatum*, planting density, Cultivar

INTRODUCTION

Among the many species of the genus *Limonium, Limonium sinuatum* is the most commonly cultivated and highly recognized cut flowers crop. The common name "Statice" is actually used in most references for this genus although "sea lavender" is alternatively used because of its lilac-colored flowers and the fact that it naturally inhabits mainly coastal areas (Steven, 2008). The cultivars of *L. sinuatum* is commonly known as the 'Sun Bird' series and are branded like 'Yellow Sun Bird' and 'Giant Blue Bird'.

Ethiopian flower exports to the global market have increased five-fold between 2006 and 2008. In 2008

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alone, Ethiopia earned 114 million dollars from the floriculture industry. The country's high altitude areas provide near ideal growing conditions for most high value cut flower crops, including Roses (*Rosa hybrida* L.), Gypsophila or Baby's Breath *(Gypsophila paniculata* L.), Statice (*Limonium spp*), Carnations (*Dianthus caryophyllus* L.) and Chrysanthemum (*Chrysanthemum spp*) (EHPEA, 2009).

Among the cut flower crops grown in the country, Statice is currently in demand by new investors for a large scale production owing to its easy plant care requirement and good selling price in the auction market. Based on these facts, four well-known firms were involved in growing and exporting of this crop. However, among the operating farms, some have been forced to stop production because of the major quality and productivity issues related to fresh weight of the flowers, planting density, and cultivar selection. Despite the stated bottlenecks, a number of new farms have shown interest in growing of the crop. Among these, Freesia Ethiopia PLC is the one that decided to include the crop in its production scheme. However, unlike others, the company sought to ascertain some specific facts before launching production. Thus, finding out appropriate planting density and type of cultivars that brings better quality and yield in Ethiopian condition would be necessary to support growers to be competitive in the global market. Optimization of plant spacing in corresponding to adapted cultivar would be vital to ensure the best economic return (Khan et al., 2003). To this aim, a study was initiated to determine the effects of cultivar, planting density and their interaction effect on yield and quality of Statice.

A wide range of spacing has been used in Statice field production. Paparozzi and Hatterman (1988) used 30 cm between plants and 69 cm between rows which gives planting density of 4.8 plants/m^2 while Whipker and Hammer (1994) used 30 by 30 cm spacing between plants and rows, which is equivalent to 11.111 plants/m^2 or 111,111 plants per hectare. Wilfret et al. (1973) used two rows of plants with 30 cm between plants and 30 cm between rows. Plants were grown on raised beds 76 to 90 cm wide and 135 cm between bed centers, resulting in approximately 50,000 plants per ha.

The performance of Statice in terms of yield and quality has been reported to be substantially affected by the kind of variety selected (Dole and Wilkins, 2005; Burchi et al., 2006; Fascella and Zizzo, 2004), the growing environment and the management practice during the growing season (Starman et al., 1995).

MATERIALS AND METHODS

Study area

The study was conducted in a plastic greenhouse at Freesia Ethiopia PLC located at Sululta, Ethiopia which is 20 km away from Addis Ababa. Geographically, the area is situated at 9° 11' 0" latitude and 38° 39' 0" longitude at an average altitude of 2785 m.a.s.l. The inside temperature and relative humidity (RH) were controlled within the range of 15-20°C and 65-75%, respectively using a computerized system (Hogendoren systems) installed within the farm.

Materials

The seedlings of three *L. sinuatum* cultivars, namely 'Amazon Bird', 'Giant Blue Bird' and 'Yellow Sun Bird' were imported from The Netherlands and used for the study. Three blocks were then prepared with each having 12 experimental plots. Each plot had a size of 0.834 x 1.2 m = 1 m^2 with a distance of 80 cm between plots. The blocks were a meter apart from each other. After this, a standard wire mesh with 1.2 m width was laid along all the blocks which later helped as a support for the stems.

Experimental design and treatments

The experiment was laid out in a 3 x 4 factorial arrangement with Randomized Complete Block Design (RCBD). The treatments consisted of three cultivars ('Amazon Bird', 'Giant Blue Bird' and 'Yellow Sun Bird') and four different planting densities (4, 6, 8 and 10 plants/m^2). The experiment was replicated three times. Then, the 12 treatments combinations were assigned randomly to the experimental units within a block.

Fertilizer was applied as per the recommendation based on the result of soil analysis throughout the growing season and other management practices like weeding, raising the wire mesh, and removing of dry leaves were performed whenever necessary. Fertigation was conducted using a computerized sprinkler system in the vegetative stage and drip irrigation was used later during the flowering stage.

Measurements

Data were collected on parameters pertaining to growth, yield and quality of Statice. These parameters were studied from three to eight sample plants depending on the plant population size, except for yield parameters (Marketable and Unmarketable) wherein data were recorded on whole plot bases. Accordingly, the number of stems which have an upright stem, with sufficient stem length for export (above 45 cm), free of any mechanical and pest damage, with required fresh weight (30 to 80 g) were sorted and categorized as marketable; whereas, stems that deviated from the above stated quality parameters were considered as unmarketable stems. In addition, days to flowering was recorded as the number of days taken from the date of planting to the date on which 50% of plants in a plot started to open their flowers. The number of days taken for 50% of flowered plants to reach their harvestable stage was considered as days to first harvest. Accordingly, flowers were harvested when four spikes of a single stem had 75% of their florets opened. The first ten stems harvested were used for quality analysis and measurements were continued for six consecutive months.

Data analysis

The data collected for the different parameters were first checked for meeting the various ANOVA assumptions and the SAS version 9.2 Statistical software package was used for the analysis of variance and estimation of correlation among the response variables (Montgomery, 2005). Then data was subjected to analysis of variance using a factorial randomized complete block design (RCBD). Whenever treatment means were found to be significant,

Table 1. Effect of Planting Density and Cultivar on Days to 50% Flowering

Treatment	Days to 50% Flowering
Planting density	
4 plants per m^2	47.44
6 plants per m^2	48.55
8 plants per m^2	48.33
10 plants per m^2	48.66
LSD (5%)	ns
Cultivar	
'Amazon Bird'	53.50[a]
'Yellow Sun Bird'	45.25[b]
'Giant Blue Bird'	46.00[b]
LSD (5%)	1.1974
CV (%)	2.93

Means followed by different letters in the same column are significantly different at the 5 % level of probability; ns= non-significant difference

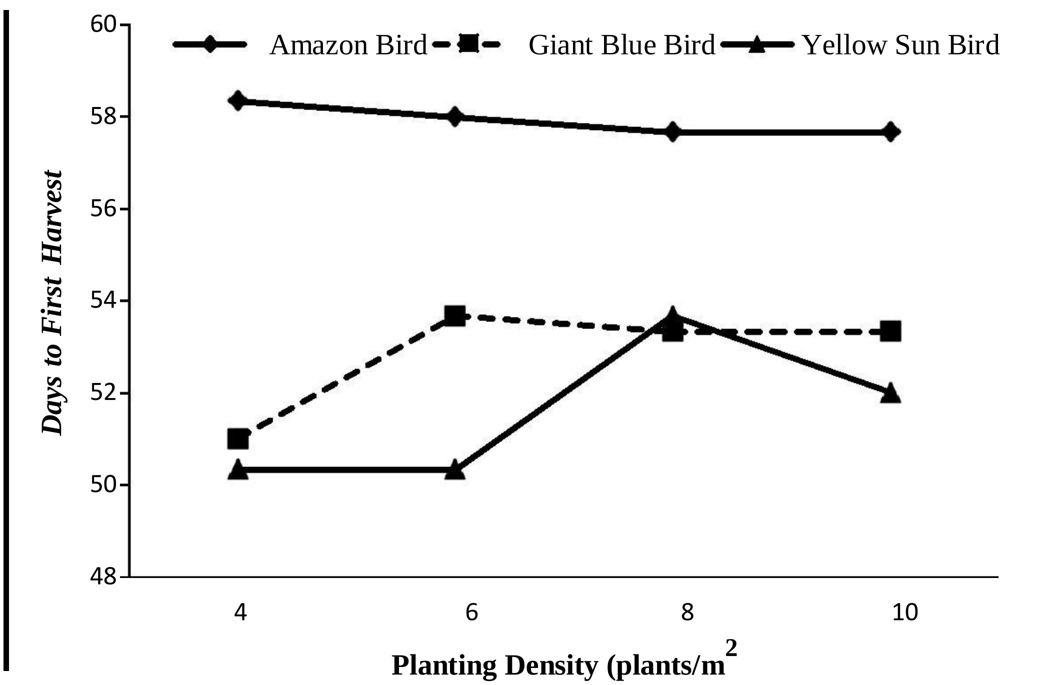

Figure 1. Influence of interaction between cultivar and planting density on days to first harvest

LSD at 5% was used to discriminate among the means.

RESULTS

Days to flowering

A highly significant (P<0.01) variation was noticed among cultivars with respect to days to 50% flowering. On the other hand, no significant results were obtained among the different planting densities and for the interaction effects between cultivars and planting densities. Accordingly, the mean comparison for cultivars revealed that 'Yellow Sun Bird' (45.25 days) and 'Giant Blue Bird' (46.0 days) flowered earlier than the 'Amazon Bird' (53.5 days) (Table 1).

Effect on days to first harvest

As depicted in Figure 1, the interaction effect between cul-

Table 2. Effect of Planting Density and Cultivar on the Number of Marketable Stems

Treatments	Number of marketable stems/m^2
Planting density	
4 plants per m^2	14.30^d
6 plants per m^2	21.15^c
8 plants per m^2	27.03^b
10 plants per m^2	30.98^a
LSD (5%)	1.0108
Cultivar	
'Amazon Bird'	19.79^c
'Yellow Sun Bird'	26.23^a
'Giant Blue Bird'	24.10^b
LSD (5%)	0.8754
CV (%)	4.42

Means followed by different letters in the same column are significantly different at the 5 % level of probability. MS=Marketable Stems; ns= non-significant difference

tivars and planting densities on days to first harvest was found to be highly significant ($P<0.01$). Accordingly, 'Amazon Bird', in all planting densities, took a much longer time than the other cultivars, perhaps attributed to the fact that this cultivar took a longer time for its vegetative stage. On the contrary, the least number of days required for first harvest was noted for cultivar 'Yellow Sun Bird' in which planting at a density of 4 and 6 plants per m^2 resulted in a first harvest within a short time (50.33 days) probably because of the vigorous growth nature of the cultivar which was observed during the growing period. However, this was not significantly different from the 'Giant Blue Bird' cultivar which was planted at a density of 4 plants per m^2 (51.00 days).

Marketable stems per plot

A highly significant ($P<0.0001$) variation was observed among the cultivars and planting densities in relation to production of marketable stems per plot. However, there appeared to be no significant interaction effect among cultivars and planting densities. As indicated in Table 2, the highest number of marketable stems (30.98) was harvested at the maximum planting density (10 plants/m^2) while the least (14.30) was obtained at the lowest planting density (4 plants/m^2). As far as the variations among cultivars are concerned, 'Yellow Sun Bird' exhibited the highest number of marketable stems (26.23) when compared with the other two cultivars.

In order to determine the production dynamics, the trend for yield of marketable stems of the three cultivars under the different planting densities was observed for six months and the data were analyzed using the mean values for each month starting from the time of harvest (October). The result reveals that the number of marketable stems increased for the first four months and declined for the last two months in all the cultivars.

Among the cultivars, 'Yellow Sun Bird' gave the highest number of stems per plot in all the months under all planting densities. The three cultivars showed higher production from November to January. Such kinds of production dynamics could help growers to schedule their labor, agronomic practices, production period, and when to cut back the whole plant or replace it (Figure 2).

Unmarketable stems per plot

A highly significant variation was observed among the cultivars and planting densities in relation to production of unmarketable stems per plot. However, the interaction effect among cultivars and planting densities was found to be non significant. Consequently, the flower stems harvested from plots of the highest planting density (10 plants/m^2) resulted in the maximum number of unmarketable stems. It appears that increased plant density has significantly raised not only the number of marketable stems but also the number of unmarketable stems. The least number of unmarketable stems were recorded for cultivar Giant Blue Bird which was statistically different from other two cultivars (Table 3).

In view of the temporal distribution of unmarketable stems of the three cultivars with different planting density, the mean values of each month (October to March) were used to analyze and determine the production dynamics. The result reveals that the number of unmarketable stems was lower for all the cultivars with their respective planting densities for the first three months but started to rise from the fourth month and reached to its highest amount in March (Figure 3). In most cases 'Amazon Bird' had the highest reject rate due to short stem length.

Quality parameters

Fresh weight

The results pertaining to fresh weight revealed that there was a highly significant variation among cultivars and planting densities. On the contrary, the interaction effect between cultivars and planting densities was found to be non significant. Referring to the effect of planting densities on fresh weight of flower stems, the obtained results depict that as planting density increased from 4 to 10 plants per m^2, fresh weight significantly decreased from 72.4 to 54.0 g (Table 4). Pertaining to cultivars difference in terms of fresh weight, 'Yellow Sun Bird' showed the highest fresh weight followed by 'Giant Blue Bird' and 'Amazon Bird' with fresh weight of 75.9, 62.2, and 56.5 g, respectively.

The mean fresh weight of flower stems of each cultivar planted at different planting densities was taken for six consecutive months and the data were analyzed using the mean values for each month (October to March). The result reveals that the fresh weight of the harvested

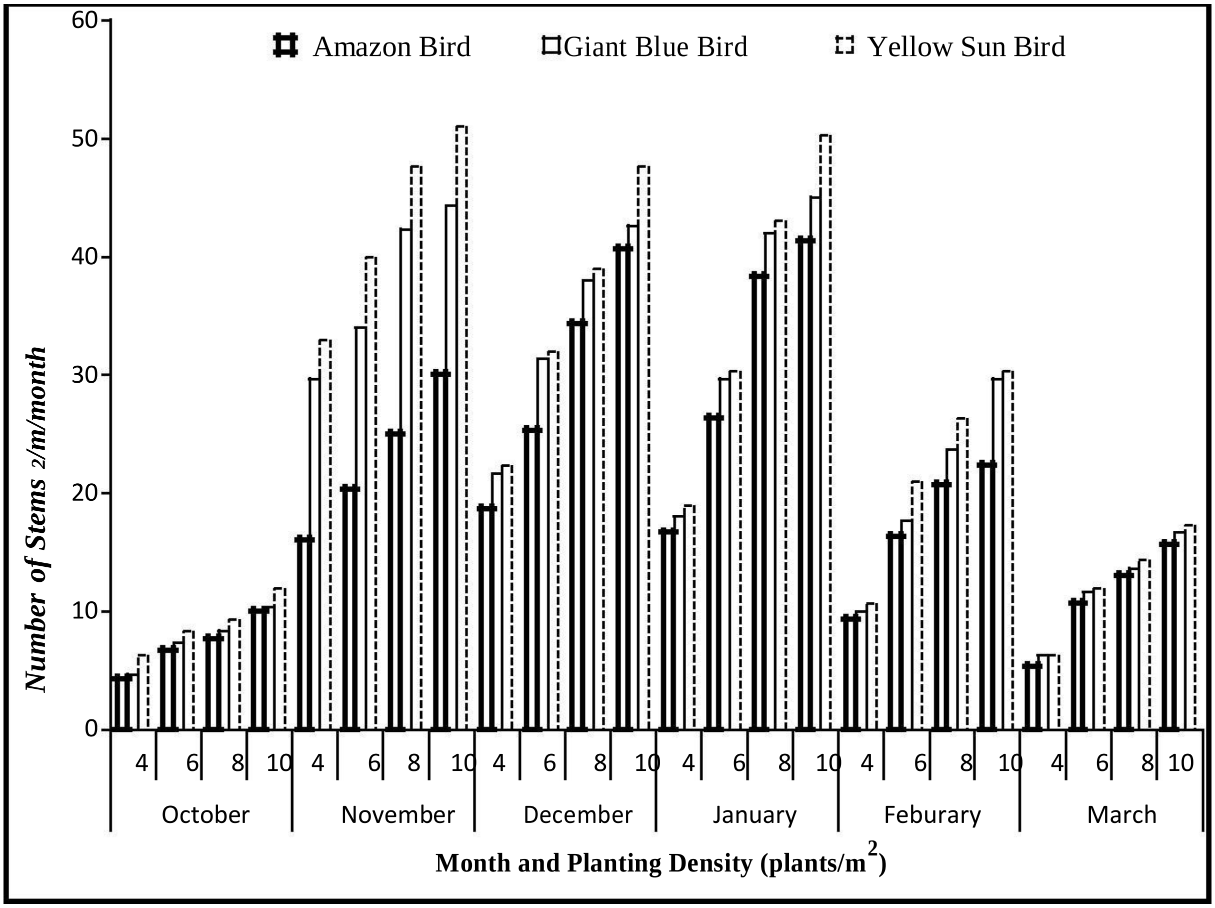

Figure 2. Trend of marketable stems of the three cultivars with different planting densities

Table 3. Effect of planting density and cultivar on the number of unmarketable stems/m^2.

Treatments	Number of unmarketable stems/m^2
Planting density	
4 plants per m^2	2.84^d
6 plants per m^2	4.53^c
8 plants per m^2	7.77^b
10 plants per m^2	11.16^a
LSD (5%)	0.5626
Cultivar	
'Amazon Bird'	7.08^a
'Yellow Sun Bird'	6.75^a
'Giant Blue Bird'	5.88^b
LSD (5%)	0.4872
CV (%)	8.75

Means followed by different letters in the same column are significantly different at the 5 % level of probability; ns= non-significant difference

stems increased for the first two months and started to decrease in the next four months in all the cultivars and planting densities (Figure 4). The stems started to become unmarketable starting from February when the weight of each stem was less than the required quality (< 30 g).

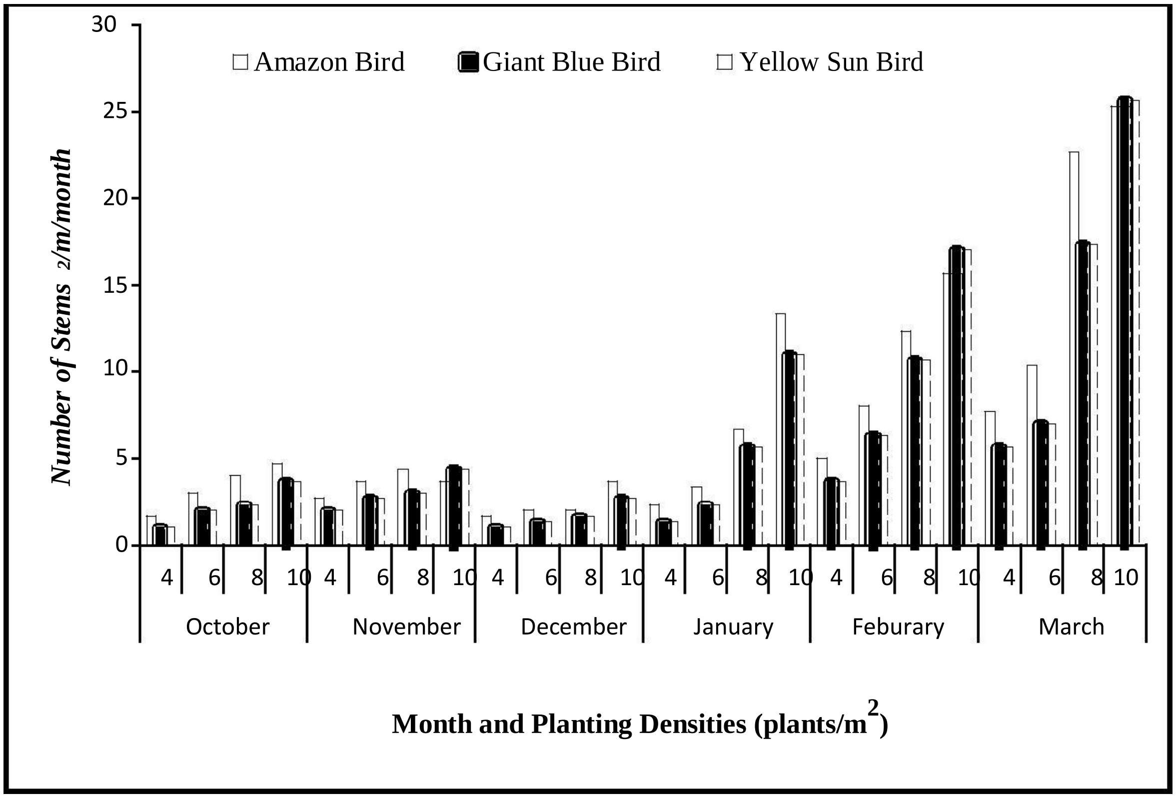

Figure 3. Trend of unmarketable stems of the three cultivars with different planting densities.

Table 4 . Effect of planting density and cultivar on fresh weight flower stems.

Treatment	Fresh weight of flower stems (g/m^2)
Planting density	
4 plants per m^2	72.38[a]
6 plants per m^2	68.99[b]
8 plants per m^2	64.06[c]
10 plants per m^2	54.00[d]
LSD (5%)	2.2381
Cultivar	
‘Amazon Bird’	56.52[c]
‘Yellow Sun Bird’	75.87[a]
‘Giant Blue Bird’	62.17[b]
LSD (5%)	1.9383
CV (%)	3.53

Means followed by different letters in the same column are significantly different at the 5 % level of probability; ns= non-significant difference

Number of branches per stem

Highly significant variation was observed among cultivars in terms of the number of branches produced. Accordingly, cultivar ‘Giant Blue Bird’ was revealed to have many more branches per stem when judged against the other two cultivars (Table 5).

Number of spikes

The tested cultivars varied significantly with respect to

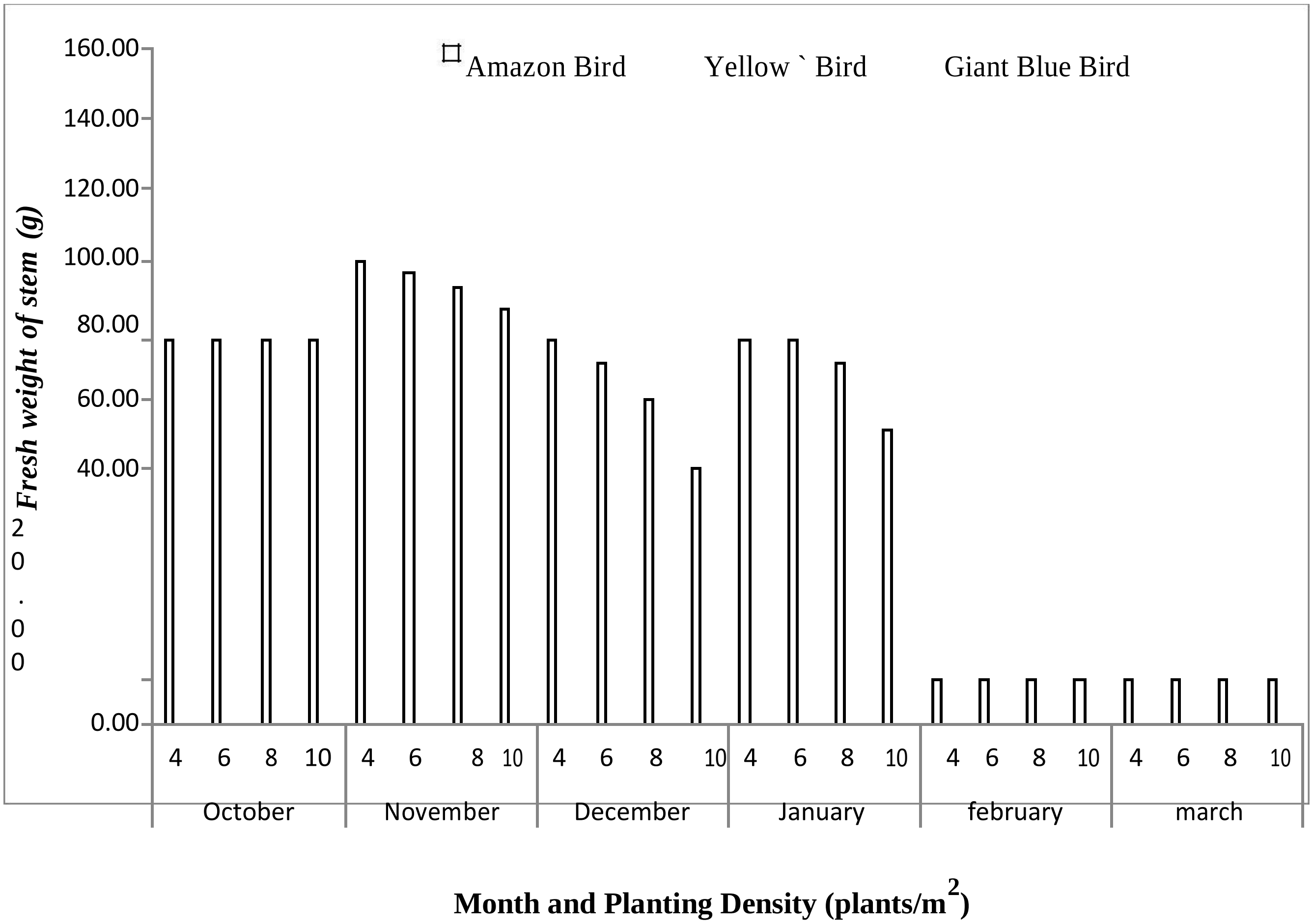

Figure 4. Trend of Fresh Weight of the three Cultivars with Different Planting Densities for six months

Table 5. Effect of planting density and cultivar on number of branches

Effects and levels	Number of branches per plant
Planting density	
4 plants per m^2	4.08
6 plants per m^2	4.19
8 plants per m^2	3.98
10 plants per m^2	3.93
LSD (5%)	ns
Cultivar	
'Amazon Bird'	3.70^c
'Yellow Sun Bird'	3.89^b
'Giant Blue Bird'	4.54^a
LSD (5%)	0.3404
CV (%)	9.94

Means followed by different letters in the same column are significantly different at the 5 % level of probability; ns= non-significant difference

the number of spikes produced. On the contrary, planting density and the interaction effect between the cultivars and the planting densities was found to be non significant. The results in Table 6 shows that the number of spikes produced by cultivar 'Giant Blue Bird' were higher than the other cultivars.

Table 6. Effect of planting density and cultivar on number of spikes

Effects and Levels	Number of spikes
Planting density	
4 plants per m^2	8.30
6 plants per m^2	7.72
8 plants per m^2	7.55
10 plants per m^2	7.73
LSD (5%)	ns
Cultivar	
'Amazon Bird'	6.83^b
'Yellow Sun Bird'	6.90^b
'Giant Blue Bird'	9.75^a
LSD (5%)	0.5116
CV (%)	7.72

Means followed by different letters in the same column are significantly different at the 5 % level of probability; ns= non-significant difference

Table 7. Effect of planting density and cultivar on stem length

Effects and levels	Stem length (cm)
Planting density	
4 plants per m^2	71.57^c
6 plants per m^2	74.10^b
8 plants per m^2	75.14^b
10 plants per m^2	78.23^a
LSD (5%)	2.0621
Cultivar	
'Amazon Bird'	68.24^b
'Yellow Sun Bird'	78.54^a
'Giant Blue Bird'	77.50^a
LSD (5%)	1.7858
CV (%)	2.82

Means followed by different letters in the same column are significantly different at the 5 % level of probability; ns= non-significant

Stem length

The height of flower stems exhibited a highly significant variation among cultivars and planting densities. As a result, maximum stem length (78.23 cm) was obtained from the highest planting density (10 plants per m^2) while the lowest stem length was noticed from smallest planting density (4 plants per $m^{2)}$). Among the cultivars, highest stem length (78.54 cm) was recorded from 'Yellow Sun Bird' which however was at par with cultivar 'Giant Blue Bird' (Table 7).

Vase life

A highly significant (P<0.01) difference was observed from the interaction between cultivars and planting densities with respect to the vase life of flower stems. The maximum number of days was recorded from cultivar 'Amazon Bird' planted at a density of 4 plants per m^2 (18.50). The shortest vase life was witnessed from 'Yellow Sun Bird' planted at 10 plants per m^2 (10.91) (Figure 5).

DISCUSSION

Determining the optimum plant density for high value crops like Statice is vital to effectively contend in international markets which always demands superior quality products. Plant density affects plant growth as well as the yield and quality of crops. Plant density effects may vary with genotype, agro-climate condition of the growing area, etc (Singh et al., 2011).

The findings of this study have shown obvious variations among the means of the evaluated parameters used to assess the yield and quality of cut Statice cultivars.

From the present experiment, the significant effect of cultivars on the days to 50% flowering was demonstrated. This result possibly occurred due to the inherent varia-bility that exists in the respective cultivars. Zizzo et al. (2003) reported similar types of variations.

The combined influence of planting density and cultivars on days to first harvest might be attributed to the dissimilarity of the cultivars in terms of growth nature. Such possible explanation was also forwarded by other authors (Dole and Wilkins, 2005; Tabassum et al., 2002).

On the other hand, the number of marketable flowers revealed an increasing trend with increasing planting densities. This result illustrated the existence of a positive relationship between planting densities and marketable yield. Obviously, as the number of plants per unit area increased, more marketable stems per unit area could be obtained provided that each plant has the capability to produce more under high competition. These results are in agreement with those of Mili and Sable (2003). On the contrary, it appears that increased plant density had increased not only the number of marketable stems but also the number of unmarketable stems. This may be substantiated by the fact that as the plants were crowded due to space limitation, their stem apparently tended not to grow upright resulting in stem-interlocking and then twisting and bending. Moreover, competition for light in crowded conditions may lead to lower photosynthate production and hence results in weaker and lighter (< 30 g) stems. The result obtained in this study is in conformity with what has been reported by Hossain et al. (2003). These authors suggested that optimum plant density guarantees the plants to grow properly through efficient consumption of solar radiation and nutrients.

Regarding the temporal distribution of the flower stem gross product of the three cultivars under different plan-ting densities, the result obtained reveals the existence of

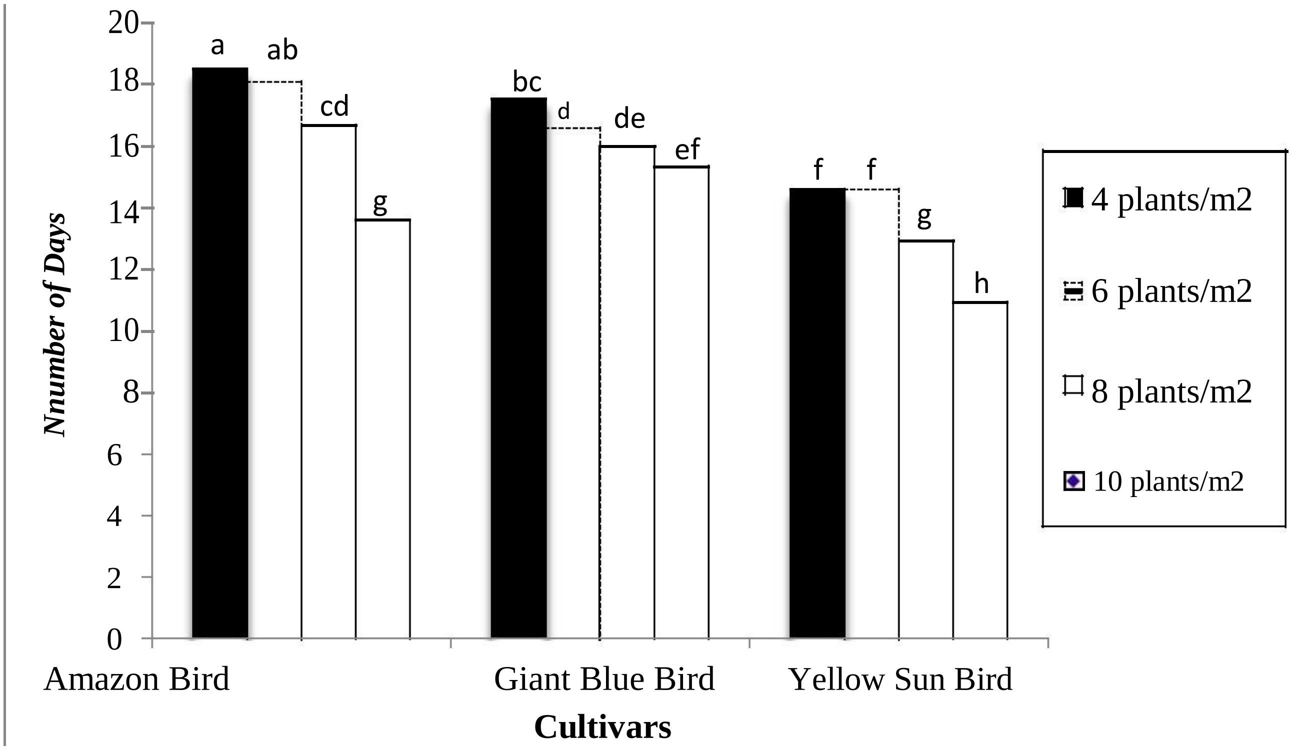

Figure 5. Influence of interaction effect of cultivar and planting density on vase life.

parallel relationship between marketable and unmarked-able yield. Proportionally, unmarketable yield for 'Amazon Bird' was found to be much higher than the other cultivars. Understanding of the yield dynamics throughout the length of the harvest period could help growers to schedule their labor, agronomic practices, production period, and when to cut back the whole plant or replace it.

The occurrence of variation in flower stem fresh weight due to differences in plant density and cultivar might be credited to the limited dry matter accumulation in the stems at higher planting densities owing the severe competition for light and nutrients and inherent variability of the genotypes. This result is in agreement with fact stated by Christine (1996).

The enlarged stem length due to varying of the plant density could be associated with the increased plant population per unit area which may cause poor light interception. Similar ideas were declared by Paparozzi and Hatterman (1988), Starman et al. (1995) and Christine (1996).

Similarly, in agreement with the present study, stem length was reported to vary with cultivar and spacing (Tabassum et al., 2002; Bakheit et al., 2012).

On the other hand, the observed higher vase life in the lower planting density might be due to the adequacy of the nutrients which ensured the presence of enough stored food in the harvested stems (Ghaffoor et al., 2000; Da Silva, 2003; Kazemi et al., 2011).

Conclusion

Foreign export is a key factor for building the economy of developing countries like Ethiopia. The floriculture industry in Ethiopia has been rapidly growing for the last five years. The country with all its resources has a big potential to expand its Agricultural export. Despite all these facts, research back up is known to be minimal.

In general, the investigation proved the existence of valid effects on the yield and quality of Statice as plant density and cultivars were varied. Cultivars 'Giant Blue Bird' and 'Yellow Sun Bird' exhibited the best performance in most of the considered quality and yield parameters and therefore can be recommended for the highlands area of Ethiopia. Moreover, from the tested planting densities, 10 plants per m^2 had shown better results as compared to the other densities in terms of marketability, premium fresh weight and stem length. For realistic recommendation, however, further research should be conducted to find ways on how to deal with issues such as vase life improvement and the like.

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