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GROWTH AND YIELD RESPONSE OF BROCCOLI (*Brassica oleraceae* L. var. Italica) VARIETIES AS INFLUENCED BY PLANTING DATES UNDER SEMI-ARID CONDITIONS

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A field experiment was conducted to evaluate the effect of different planting dates (15th September, 1st October, 15th October, 1st November and 15th November) on the growth and yield of Rocco F_1 and Galabrease varieties of broccoli under semi-arid condition of Dera Ismail Khan, Pakistan. Experiment was laid out in Randomized Complete Block Design (RCBD) in a split-plot arrangement with three replications. Varieties were assigned to main plots and planting dates were allotted to sub-plots. Growth parameters *viz*. head diameter, number of axillary shoots, leaf chlorophyll content and days taken to maturity: and yield parameters such as fresh and dry biomass, apical head weight, axillary shoots weight and total marketable yield were measured. Results showed that Rocco F_1 performed better than Galabrease on all the growth parameters except leaf chlorophyll value. Maximum head weight (315.84 g), axillary shoots weight (180.99 g), fresh biomass (67.85 t/ha), dry biomass (12.43 t/ha) and total yield (19.83 t/ha) was recorded in Rocco F_1. The increase in all yield parameters of Rocco F_1 over Galabrease was more than 100 %. As regards planting dates, 1st October proved significantly better than other planting dates on various growth and yield parameters. Planting of broccoli latter than 1st October reduced growth and yields significantly and linearly. The decrease in total yields ranged from 13.88 to 181.37 % when broccoli was planted earlier than 1st October or later than this date. Interactions between varieties and various planting dates were significant. It is concluded from the present findings that Rocco F_1 proved better than Galabrease while best planting time for both the varieties was found to be the first week of October. Planting of broccoli earlier or later than first week of October adversely affected the yields.
Keywords: Brassicaceae, *Brassica* vegetables, cole crops, broccoli, sowing time, yield potential.

INTRODUCTION

Broccoli (*Brassica oleracea* L. var. Italica) is a widely cultivated vegetable in the world. It is known as the "Crown Jewel of Nutrition". A 100 g broccoli has only 40 calories and have sufficient amount of vitamins (A, B-complex, C), 50 mg calcium and 1.7 mg iron (Splittstoesser, 1990). One of the most appealing characteristics of broccoli is its high (82-140 mg) vitamin C (Albaracin *et al*., 1995; Vural *et al*., 2000). It is also rich source of phytochemicals which protect against certain cancers and heart disease (Wargovich, 2000; Keck *et al*., 2004). Epidemiological evidence shows that diets rich in *Brassica* vegetables, such as broccoli, are associated with a lower risk of lung and colorectal cancer. About 56% of the case-controlled studies demonstrate a strong relationship between increased broccoli consumption and the protection against cancer (Gliszczyńska-Swigło *et al*., 2006; Higdon *et al*., 2007). This defensive effect has largely been attributed to phytochemicals present in broccoli that mainly contains the vitamin C (Podsedek, 2007).

In Brassicaceae family, broccoli attracted more attention throughout the world due to its multifarious use and great nutritional value (Talalay and Fahey, 2001; Rangkadilok *et al*., 2002, 2004). In Pakistan, broccoli is cultivated on a very limited scale in scattered areas near big cities but its increasing popularity and demand is now gaining grower's interest.

Many farmers in the country have had little or no profitable choice but to produce crops which are commonly in surplus. Rapid economic growth and continued population growth in the region are also driving expansion of both volume and diversity of products. The literature also strongly supports the notion that new crops development could provide opportunities for enhanced agricultural sustainability (Busch, 1997; Faroque *et al*., 2011).

There are several ifs and buts associated while shifting towards the commercial production of a new crop, which need to be addressed first. Our neighbors China and India are the leading producers of broccoli (FAOSTAT, 2013) while in Pakistan, no scientific research has been carried out on

broccoli cultivation except that reported earlier in Rawlakot (Ahmed and Siddique, 2004).

Broccoli prefers cool moist climate for growth and a temperature range of 16-18°C for its quality curd development (Lestrange *et al*., 2010). Plants subjected to temperature 0-3.3°C negatively affect the growth and head quality. Moreover, it is known that the low temperature during head formation results in reduction in main stem size. On the other hand high temperatures (30°C) results in early flower initiation and reduction in quality parameters (Bjorkman and Pearson, 1998).

In crop husbandry, the economic yield varies with sowing date due to difference in total dry matter accumulation potential. In general, such a difference between the cultivars is not closely linked to differences in the relative growth rate or any growth parameter but is related more to the growth duration. Therefore, it is imperative to optimize sowing time for obtaining maximum yield along with quality of vegetable (Csizinszky, 1996). Previous research findings also suggest that optimum planting time is critical as it directly affects yield and quality of broccoli (Sari *et al*., 2000). Many research workers showed that medium planting date proved better than early or late planting of broccoli (Ahmed and Siddique, 2004; Hossain *et al*., 2011; Abou El-Magd, 2013; Karistsapol *et al*., 2013). The agro-climatic condition of Dera Ismail Khan District favours successful cultivation of other members of cole crops like cauliflower and cabbage, which are widely grown in the area during the fall winter months (Oct-March). Broccoli is a new introduction to the study area but no research work has ever been carried out in the past on its cultivation. It is imperative to investigate various aspects of cultivation, and optimum time of planting is an important aspect for getting profitable yields. Therefore, a maiden study was carried out to optimize sowing time for obtaining maximum potential yield under the semiarid conditions of Dera Ismail Khan, Khyber Pakhtunkhwa (KPK), Pakistan.

MATERIAL AND METHODS

A field experiment was conducted at Agricultural Research Institute, Dera Ismail Khan, KPK, Pakistan during 2013-2014. The experiment was laid out in a Split-Plot design with three replications. Varieties Rocco and Galabrease were assigned to main plots and planting dates were allotted to sub-plots. Planting dates were 15th September, 1st October, 15th October, 1st November, and 15th November. The seeds were sown on raised nursery beds at a distance of 2 centimeters in shallow lines 20 cm apart. Water was applied with the help of sprinkler as and when required. Experimental field was prepared by proper ploughings and rotavated twice to break the clods. Farm yard manure (FYM) was added at the rate of 15 t/ha. The seedlings were transplanted after 30 days of sowing to experimental plots. The plot size was maintained at 3m x 4m. The plant-plant and row-row distance was kept as 30 and 60 cm, respectively. Fertilizers were applied at the rate of 120-80-80 kg/ha. Urea (46% N), Single Super Phosphate (18% P_2O_5) and Potassium sulfate (50% K_2O) were used as sources of NPK. Nitrogen was applied in two split doses. The first dose was applied at the time of transplantation whereas; remaining half was top dressed 5 weeks after transplantation. The data were collected on growth parameters of 10 randomly selected broccoli plants *viz*. head diameter was measured using Vernier caliper, number of axillary shoots were counted at maturity, leaf chlorophyll content was measured at the time of apical head maturity with the help of Konica Minolta SPAD-502 chlorophyll meter, days taken to maturity were counted from the date of nursery sowing to apical head maturity, and for yield parameters 10 randomly selected plants were tagged to obtain accurate data of total yield/plant and then average was calculated to obtain total yield in tons/ha. Digital balance was used to measure head weight and axillary shoots weight. For fresh biomass tagged plants were harvested and weight of head and axillary shoots was added to obtain total biomass/plant in order to calculate fresh biomass in tons/ha. Same method was applied for the collection and calculation of dry biomass in which plants were oven dried at 80°C for 48 hours. Crop was harvested at maturity when the heads attained full compact size before the opening of any floral primordia. A net plot size of 12 m^2 was harvested.

Data obtained on various parameters were subjected to analysis of variance according to the procedures given by Steel *et al*. (1997). Means of varieties and planting dates were compared with one another using Least Significance Difference test of significance using computer analytical software Statistix 8.1.

RESULTS

***Growth parameters*:** Data collected on the head diameter as influenced by various planting dates on two varieties of broccoli (Table 1) showed that Rocco F_1 plants had significantly larger head diameter (14.81 cm) than Galabrease plants (11.52 cm). The increase in head diameter over Galabrease was 28%. As regards the effect of various planting dates, plants sown on 1st October had significantly different and larger head diameter (14.50 cm) than the plants sown on other planting dates. In plants sown later than 1st October, the head diameter was reduced significantly and linearly. Interactions between various varieties and planting dates were significant. Rocco F_1 plants sown on different planting dates had significantly larger head diameter than Galabrease plants (Fig. 1). Number of axillary shoots showed that Rocco F_1 had significantly higher side shoots per plant (6.13) than Galabrease variety (5.80) with an increase of about 6% (Table 1). As regards planting dates, 7.3 shoots per plant were found in plots planted on 1st October which was significantly different from other plots planted on other dates except 15th

Table 1. Effect of varieties and planting dates on the growth parameters of broccoli.

Treatments	Head diameter (cm)	No. of Axillary shoots	Leaf Chlorophyll Content	Days taken to maturity
Varieties				
Rocco F_1	14.81a	6.13a	68.40b	132.49a
Galabrease	11.52b	5.80b	73.57a	123.63b
$LSD_{0.05}$ for varieties	2.114	0.319	0.483	0.980
Planting Date				
15th September	13.83b	7.1a	71.61a	129.20b
1st October	14.50a	7.3a	71.91a	128.40b
15th October	13.28c	6.4b	70.90a	127.57b
1st November	12.19d	5.4c	70.68a	131.20a
15th November	12.03d	3.4d	69.82a	123.93c
$LSD_{0.05}$ for sowing dates	0.488	0.600	2.311	1.949

Means followed by similar letter in each column for each factor do not differ significantly from one another at 5 % level of significance.

September (7.1) which was at par with 1st October. Regarding interactions between varieties and planting dates, the results were significant. On each planting date, there was significantly higher number of shoots per plant in Rocco F1 than the local variety Galabrease (Fig. 2).

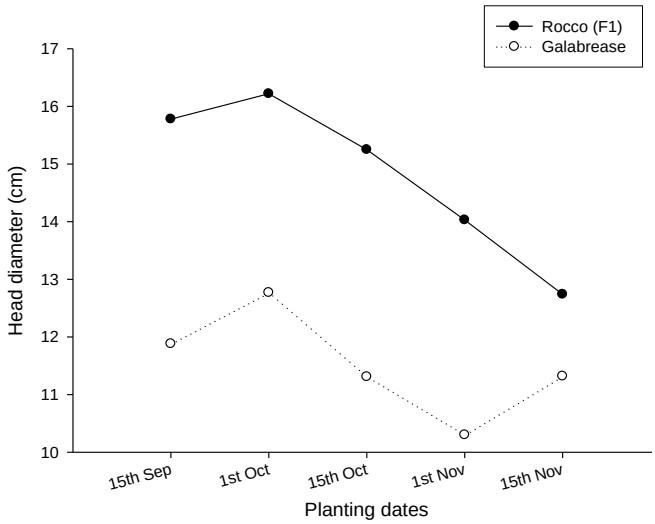

Figure 1. Interaction effect of planting dates and varieties on head diameter (cm).

Leaf chlorophyll content of broccoli was significantly affected by varieties and the interactions with planting dates (Table 1). Leaves of Galabrease variety had significantly higher chlorophyll content (73.57 µmol /m^2) than Rocco F^1 (68.40 µmol /m^2) with an increase of about 8%. Though the effect of planting dates on leaf chlorophyll content was nonsignificant, the highest leaf chlorophyll content of 71.91 µmol/m^2 was observed in plants sown on 1st October. As regards interactions between varieties and planting dates, plants of Galabrease variety had significantly higher chlorophyll content than Rocco F^1 variety in all plots planted on different dates (Fig. 3).

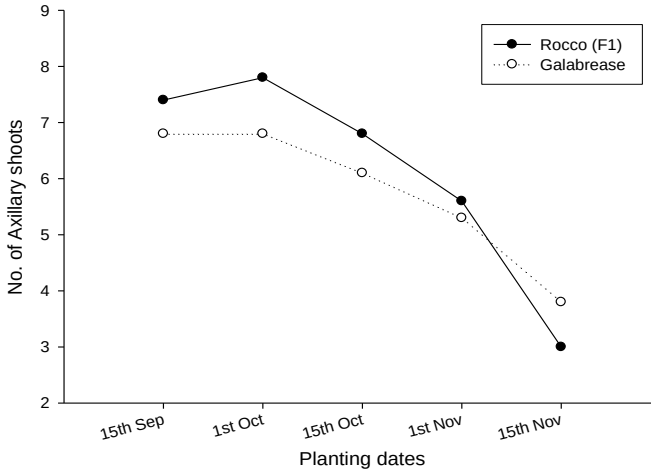

Figure 2. Interaction effect of planting dates and varieties on no. of axillary shoots weight (g).

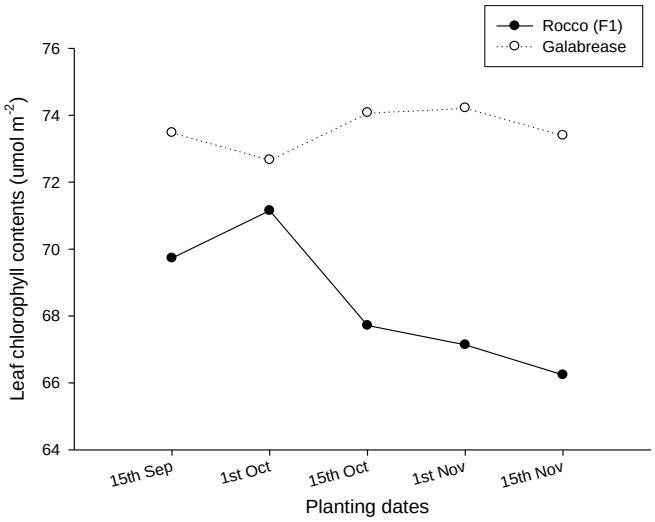

Figure 3. Interaction effect of planting dates and varieties on chlorophyll contents (µmol/m^2).

Data collected on days taken to maturity (Table 1) showed that Rocco F^1 took longer period to maturity (132.49 days) being significantly different from Galabrease variety (123.63 days). The increase in length was 7%. As regards the effect of planting dates, the plants took significantly longer period (131.20 days) when sown on 1st November than all the other dates of planting. Interactions between varieties and planting dates taken to maturity were also significant. Plants of Rocco F_1 took longer period to maturity when sown on different planting dates than Galabrease (Fig. 4).

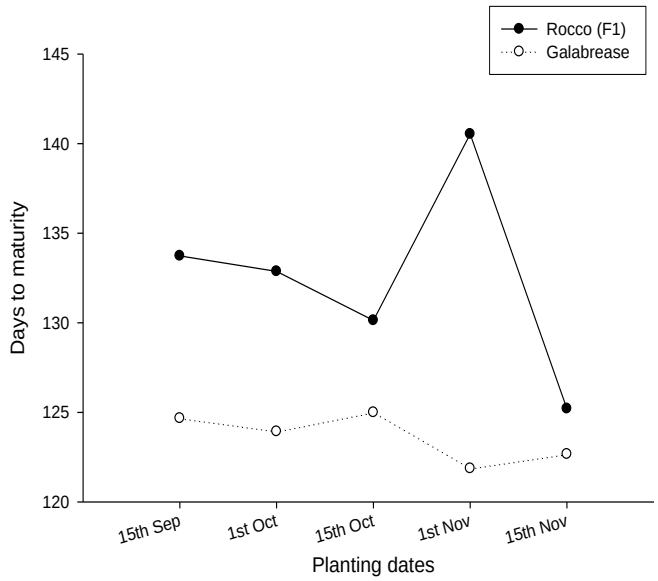

Figure 4. Interaction effect of planting dates and varieties on days to maturity.

***Yield parameters*:** Trends in various yield parameters as influenced by various planting times on Rocco F_1 and Galabrease varieties of broccoli are almost same as growth parameters. Data recorded on fresh biomass (Table 2) showed that Rocco F_1 produced significantly higher yield of fresh biomass (67.85 t/ha) than Galabrease (54.47 t/ha) with an increase of about 25%. As regards the effect of various planting dates, it can be seen that plots sown on 1st October out-yielded (73.64 t/ha) other planting dates except 15th September (70.67 t/ha) which was comparable with 1st October. Regarding various interactions between varieties and different planting dates, it was observed that Rocco F_1 produced significantly higher fresh biomass at different planting dates than Galabrease variety. However, both the varieties produced less fresh biomass when planted later than 1st October. Trend in dry biomass was almost same as fresh biomass. The results on dry biomass (Table 2) showed that Rocco F_1 produced significantly higher dry biomass (12.43 t/ha) than Galabrease (9.84 t/ha) with an increase of 26%. Regarding the effect of various planting dates, it can be visualized that plots sown on 1st October produced the highest yield of dry biomass (13.48 t/ha) being significantly different from other dates of planting except 15th September (12.78 t/ha). Regarding interactions between varieties and different planting dates, the results were nonsignificant. However, higher yields of dry biomass were found when Rocco F_1 was planted on different dates than Galabrease. Data obtained on the effect of different planting dates on apical head weight (Table 2) showed that Rocco F_1 had significantly higher apical head weight per plant (315.84 g) than 138.55 g per plant of Galabrease with an increase of about 130%. As regards planting dates, plants sown on 1st October had significantly higher weight of apical head per plant (299.99 g) than the other planting dates except 15th September (286.17 g) which was at par with the former one. However, apical weight of plants sown later than 1st October was reduced significantly. Interactions between varieties and different planting dates were significant. Rocco F_1 had significantly higher apical head weight per plant in all the plots sown at different dates than Galabrease (Fig. 5). Axillary shoots weight per plant (Table 2) showed that the main effects of varieties and planting dates were significant. Rocco F_1 had

Table 2. Effect of varieties and planting dates on the yield parameters of broccoli.

Treatments	Fresh Biomass (t/ha)	Dry Biomass (t/ha)	Apical Head wt. (g)	Axillary shoots wt. (g)	Total yield (t/ ha)
Varieties					
Rocco F1	67.85a	12.43a	315.84a	180.99a	19.83a
Galabrease	54.47b	9.84b	138.55b	77.64b	8.65b
$LSD_{0.05}$ for varieties	7.491	1.598	44.007	44.236	0.395
Planting Date					
15th September	70.67a	12.78a	286.17a	171.41b	18.30b
1st October	73.64a	13.48a	299.99a	221.10a	20.84a
15th October	64.13b	11.61b	189.56b	150.26c	13.89c
1st November	55.02c	9.93c	203.84b	76.35d	11.21d
15th November	42.35d	7.87d	156.43c	27.46e	7.36e
$LSD_{0.05}$ for sowing dates	4.047	0.807	16.937	16.343	0.992

Means followed by similar letter in each column for each factor do not differ significantly from one another at 5 % level of significance.

significantly higher axillary shoots weight/plant (180.99 g) than Galabrease (77.64 g) with an increase of about 132%. Comparing the planting dates with one another, it was observed that the significantly highest axillary shoots weight per plant was found in plants sown on 1st October, and the weight reduced significantly and linearly in plots planted later than 1st October. The interactions between varieties and different planting dates were found significant. The significantly higher weights per plant were observed in case of Rocco than Galabrease in different dates of planting.

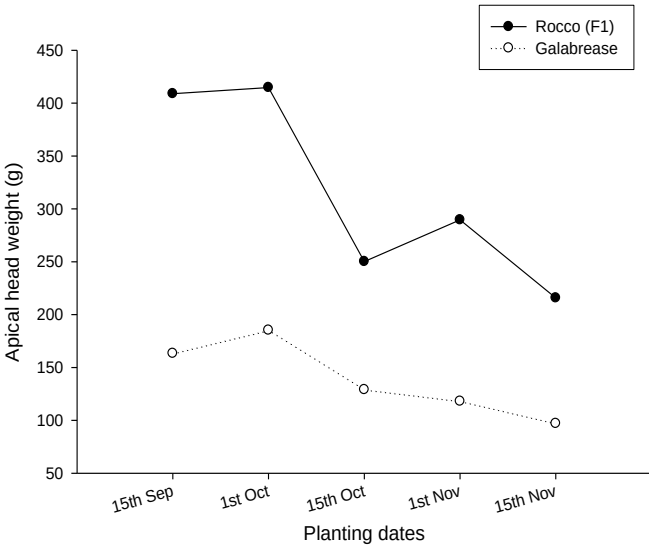

Figure 5. Interaction effect of planting dates and varieties on apical head weight (g)

It can be visualized from the data collected on the total yield (t/ha) of broccoli (Table 2) that Rocco F_1 had significantly higher yield of 19.87 t/ha than Galabrease (8.65 t/ha) with an increase of about 130%. Regarding planting dates, significantly highest yield of 20.84 t/ha was obtained in plots sown on 1st October being different from the other dates of planting followed by 18.30 t/ha from plots sown on 15th September. In plot sown later than 1st October, yields were reduced significantly and linearly. Interactions between varieties planting dates on total yield of broccoli were found significant. Rocco F_1 produced significantly higher yields sown on different planting dates than the Galabrease variety (Fig. 6).

Correlation between various growth and yield parameters showed that the various growth parameters were significantly correlated with various yield parameters of both the varieties. Axillary shoots number, head diameter, and days to maturity of Rocco F_1 had significantly positive correlation with total yield (r = 0.94, 0.95, 0.33, respectively). In case of Galabrease, axillary shoots number, and days to maturity also showed significantly positive correlation with total yield (r = 0.91, 0.83, 0.62, respectively).

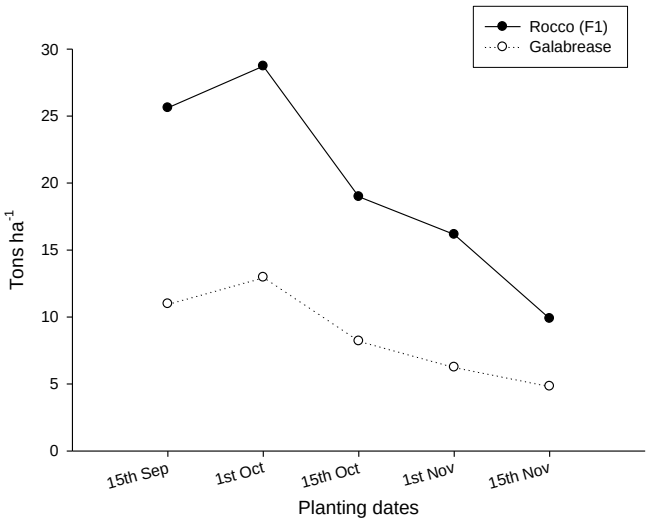

Figure 6. Interaction effect of planting dates and varieties on total yield (t/ha).

DISCUSSION

Broccoli is a highly thermo-sensitive crop and a strong influence of temperature has been reported by many researchers (Mourao and Brito, 2000; Kaluzewicz *et al*., 2002). Planting dates affected growth and yield of both the varieties (Rocco F_1 and Galabrease) significantly. Trends in various growth and yield parameters were almost same. Medium planting time proved better than early or late planting of broccoli irrespective of variety under the agro-climatic conditions of D.I. Khan. Main effects of varieties and planting dates as well as their interactions showed that all the growth and yield parameters were significantly affected by main effects as well as interactions. Looking at the growth parameters; head diameter of both varieties decreased significantly after 1st October. This decrease in head diameter with later plantings might be due to the onset of lower temperature during the early growth phase of broccoli plants switching them earlier to reproductive phase. Our results are well supported by Kaluzewicz *et al*. (2012) and Sermenli *et al*. (2011) who reported that head diameter in broccoli is largely dependent on temperature and it varies with the variation in planting time. Larger variations in head diameter among the broccoli cultivars and different sowing dates were also reported by many scientists (Abou El- Magd *et al*., 2005; Garcia *et al*., 2006; Hanaa *et al*., 2010; Hanaa, 2011). These results are in line with Hossain *et al*. (2011) who recorded maximum head diameter on 1st October sowing. Decrease in head diameter with later plantings are also supported by Sari *et al*. (2000) and Shapla *et al*. (2014). Number of axillary shoots also declined in both varieties after 1st October. Higher number of axillary shoots in Rocco and in both varieties on 1st October sowing might be due to the availability of suitable temperature for their development as their production is

genotype and temperature dependent (Wien and Wurr, 1997). Similar decreases in axillary shoot number with later plantings were recorded by Shapla *et al*. (2014) and Hafiz *et al*. (2015) which strongly support our results. The highest amount of chlorophyll in "Galabrease" seems to be its genetic trait. Acikgoz (2011) also reported differences in chlorophyll contents among different cultivars of broccoli. Small variations recorded during different sowing dates also shows that temperature and photoperiod also have some effects on leaf chlorophyll contents, but the results of present study shows that the growing period did not influenced the chlorophyll content of broccoli. These results are in line with Kalisz *et al*. (2013) who found no influence of growing period on the chlorophyll content of Chinese flat cabbage. Maturity of broccoli largely depends on temperature. Low temperature favors maximum vernalization, thereby switching the plants earlier to generative phase (Wien and Wurr, 1997; Grevsen and Olesen, 1999). Reason behind the earlier maturity in later plantings might be credited to the lower temperature during the months of November and December. Our results are in agreement with Lindemann-Zutz *et al*. (2016) who reported a shorter time in broccoli development, if the plants receive cool temperature at earlier stages. Hossain *et al*. (2011) and Shapla *et al*. (2014) also recorded minimum days to maturity with later sowings.

Outcome of the yield parameters also pointed out a strong effect of temperature as well as the genotypes. Fresh biomass and dry biomass were largely affected by sowing dates. Higher fresh and dry biomass on 1st October sowings in the present study are validated by Abou El-Magd (2013) who reported similar outcomes of increased fresh and dry biomass on 1st October sowing in broccoli. The reason behind lower biomass in later plantings might be due to the lower temperature during the initial growth phase of broccoli swapping the plants earlier to generative phase, thereby shortening the vegetative growth period which resulted in lower fresh and dry biomass. Apical heads are the main marketable commodity produced in broccoli. Greater the head weight more the marketable yield and hence greater return to the farmers. Higher head weights of Rocco and Galabrease on 1st October sowings are in agreement with Hossain *et al*. (2011) who recorded maximum head weight of broccoli on 1st October sowing. Decline in the head weight of both varieties after 1st October planting are supported by Khatun *et al*. (2012), Shapla *et al*. (2014) and Hafiz *et al*. (2015). Results on the weight of axillary shoots also exhibited the same trend. Our results of maximum axillary shoot weight on 1st October sowing are comparable with the findings of Hossain *et al*. (2011). As the various yield parameters were affected by planting dates, similarly total yield had the same trend in case of both the varieties. Total yield decreased significantly and linearly after 1st October in both the varieties. Our results are in 100% agreement with the findings of Hossain *et al*. (2011) who recorded maximum total yield on 1st October sowing and decline thereafter.

Many research workers (Hossain *et al*., 2011; Abou El-Magd., 2013; Karistsapol *et al*., 2013) working on broccoli in different countries reported that medium planting dates proved better than early or late plantings which strongly endorse the results of our study.

***Conclusions*:** It can be concluded from the present piece of research that Rocco F_1 proved better than Galabrease variety of broccoli as regards their effect on various growth and yield parameters. First week of October was found as best planting time for both the varieties. Planting of broccoli in November adversely affected the yield under the semi-arid conditions of D.I. Khan.

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