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INTERACTIVE STUDY OF ROW SPACINGS AND FOLIAR APPLICATION OF MACRO AND MICRO-NUTRIENTS ON GROWTH, YIELD AND QUALITY OF SUGARCANE (*SACCHARUM OFFICINARUM* L.)

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Abstract

A proper distance among the crop plants ensures efficient use of applied materials by the plants, thus affecting the yield. A balanced fertilization of plant nutrients not only improves crop growth but guarantees optimal crop production. The present investigations were carried out to examine the effect of foliar application of macro and micro elements on the growth, yield and qualitative characteristics of sugarcane sown at different row spacings. The experiment was conducted on sandy clay loam soil under agro-climatic conditions of Faisalabad. A uniform dose of 200-100-100 NPK kg ha^{-1} was used as soil application. Cane crop was grown at row spacings of 75, 90 and 120 cm and sprayed with water (control), macro nutrients (N, P and K), micro nutrients (Fe and Zn) and a combination of both macro and micro nutrients (NPK + Fe and Zn). Cane diameter, cane length, stripped cane weight and stripped cane yield were significantly higher in wider row spacing of 90 to 120 cm apart rows. Crop sprayed with micro nutrients or macro + micro nutrients gave the highest cane yield. Leaf area index, leaf area duration, crop growth rate and total dry matter were significantly higher in wider row spacings and foliar applications of macro + micro nutrients. Net assimilation rate, CCS and sugar recovery were significantly higher in wider row spacing with foliar application of macro- and micro nutrients.

Introduction

It is an admitted fact that crop plants need nutrition for their growth and living. The deficiency of any nutritional element can cause adverse impact resulting in poor performance of the plants. The ultimate source of nutritional elements for plants is soil whose ability depends upon its natural fertility status and artificial amendments (Iftikhar *et al.,* 2010). Plants fulfill their nutritional requirements by absorption from soil and its deficiency may be supplemented by foliar application. The fertile soils have the capability to provide the required nutrition to the plants in the form of macro and/or micro-elements. The space required by the plants, however, is the critical one for providing proper nutrition, water and light to the crop plants. It is, therefore, essential that a suitable and effective area must be provided to a plant by growing it under suitable row to row and plant to plant distance or suitable planting technique (Ehsanullah *et al*., 2011; Babar *et al.,* 2011; Arif *et al*., 2012). Pawar *et al*., (1995) found that the stripped cane yield in close spacing was higher than wide spacing. In contrast, Nazir *et al*., (1990) obtained higher cane yield in wide spacing as well as raising the crop in pits. Distance of 90 and 120 cm between rows of sugarcane with high cane yield was recorded by Ehsanullah *et al*., (2011). Zafar *et al*., (2010) also reported high cane yield at 120 cm spacing.

As regards the nutritional elements, the need for both macro and micro-elements by the plants is essential for performing various physiological functions within the plant. The application of macro-elements (N, P and K) and micro-elements (Zn and Fe) as foliar spray invariably indicated their effects on different aspects of the development of cane crop (Fageria *et al*., 2009). Foliar application is found more practical under special conditions or problem soil (Jabeen & Ahmad, 2011). Gracia & Hanway (1976) applied a liquid of NPKS as foliar spray and found a yield increase of 27-31%. Uptake of N, P and K can be improved through foliar application of these elements when root system of the plants is not so efficient to uptake these nutrients (Mallarino *et al*., 2001). Arif *et al*., (2006) applied N and P as foliar spray on wheat and found a significant improvement in yield contributing parameters of the crop. Zinc and iron humates application and increase in the level of Fe and Zn from 0 to 5 kg ha^{-1}, increased the cane yield (Dhanasekaran & Bhuvaneswari, 2004). Soil application of Zn @ 10.0 kg ha^{-1} to the cane crop showed an increase by percentage 13.3 CCS, 22.6 brix, 84.3 purity, 19.0 pol and sugar yield was 11.9 t ha^{-1} (Ahmad *et al*., 2001). In another study, Panhwar *et al*., (2003), demonstrated that foliar application of zinc sulphate had more beneficial effects on growth and yield of sugar cane than its soil application. Similarly the foliar application of $FeSO_4$, increased growth parameters, yield and juice quality of ratoon significantly over the control (Dey & Yadav, 2005).

Keeping in view the varying responses of cane to the foliar application of nutrients (macro and micro) and sowing at different spacings, it was contemplated in this research project to quantify the effects of these two factors on quantitative and qualitative aspects of sugarcane crop under agro-ecological conditions obtaining at Faisalabad.

Materials and Methods

The proposed study was conducted on a sandy clay loam soil at Postgraduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad, during the year 2007-2008.

The composition of experimental soil showed sand 63 - 65 %; silt 14 - 16 %; clay 18 - 20 %; organic matter 0.5-0.9 %; total nitrogen (N) 0.041- 0.044 %; phosphorus (P) 1.00 ppm; potassium (K) 185 – 189 ppm; zinc (Zn) 1.24-1.74 ppm and iron (Fe) 3.47-5.08 ppm. The experiment was laid out in split block design with three replicates having net plot size 18 m × 15 m. Sugarcane variety HSF-240 was used as a test crop. Sugarcane crop was planted at three row spacings i.e. 75, 90 and 120 cm.

Crop was planted at 15th March, 2007. Foliar applications included spray of water (control), macro nutrients (N, P and K), micro nutrients (Zn and Fe) and macro + micro nutrients. Macro nutrients spray composed of N (4%), K (2%), P (1%) and micro nutrients spray consisted Zn (2%) and Fe (1%). A quantity of 500 ml of each of the above combinations was dissolved in 60-70 liters of water for foliar spray. Farm yard manure (F.Y.M) @ 10 t ha^{-1} was uniformly well mixed in soil before soaking irrigation. Seed (setts) used for planting were obtained from the crop of same age sown in a field of similar fertility status. A uniform seed rate @ 75,000 double budded setts ha^{-1} was used in each treatment. Crop was planted in March, 2007. Fertilizer was applied @ 200–100–100 kg N, P and K ha^{-1} in the form of Urea, Diammonium phosphate (DAP) and Sulphate of Potash (SOP), respectively. Two hoeings were given followed by earthing-up. First hoeing was done during 2nd week of April and second during last week of May. In all, 16 irrigations were applied, each of 10 cm ha. First spray of nutrients was done 60 days after sowing at 45 cm plant height while second was applied at 80 days after planting. The crop was harvested on 23rd February, 2008.

Observations on different agronomic traits and quality parameters were recorded using standard procedures. Commercial Cane Sugar (CCS) was calculated by the following formula (Spancer & Meade, 1963):

$$CCS\ (\%) = \frac{3P}{2}\left(1-\frac{F+5}{109}\right)-\frac{B}{2}\left(1-\frac{F+3}{100}\right)$$

where P = Pol percent first expressed juice
B = Brix percent first expressed juice
F = Fibre percent cane.

Cane sugar recovery (CSR) was calculated by the following formula (Spancer & Meade, 1963):

$$CSR\ (\%) = CCS\ (\%) \times 0.94$$

where CCS = Commercial Cane Sugar

Leaf area of five randomly selected stalks from each plot at 30 days interval was measured with portable leaf area meter Li-Cor Model LI-3000. Leaf Area Index (LAI) was computed by using the following formula as suggested by Watson (1947).

$$LAI = \frac{\text{Leaf area}(cm^2)}{\text{Ground area } (cm^2)}$$

Leaf Area Duration (LAD) was determined by using the method of Hunt (1978) as given below:

$LAD = [(LAI_1 + LAI_2) \times (t_2 - t_l)\ 1/2)]$ days
LAI_1 = Leaf area index at t_l
LAI_2 = Leaf area index at t_2
t_l = Time of LAI_1
t_2 = Time of LAI_2

Crop Growth Rate (CGR) and Net Assimilation Rate (NAR) were determined using the following formulae of Hunt (1978) as follows:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}\ (g\ m^{-2}\ day^{-1})$$

W_1 = Plant DW m^{-2} at time t_l
W_2 = Plant DW m^{-2} at time t_2
t_1 = Time of 1st harvest
t_2 = Time of 2nd harvest

$$NAR = \frac{TDM}{LAD}\ (g\ m^{-2}\ day^{-1})$$

where TDM means total above ground shoot dry matter and LAD means leaf area duration.

Data collected were analyzed statistically by employing the Fisher's analysis of variance technique and treatment means were compared by using least significance difference (LSD) test at 5% probability level (Steel *et al*., 1997).

Results

Statistical data regarding number of tillers, cane length, cane diameter, weight per stripped cane and stripped cane yield are depicted in Table 1. Number of tillers and cane length were not affected significantly either by row spacing or by foliar application of nutrients (Table 1a,b). However, thicker canes were recorded in case of wider row spacing of 120 cm (2.53 cm). In case of foliar application of nutrients, combination of both macro + micro nutrients exhibited significantly thicker canes (2.53 cm) (Table 1c).

Regarding stripped cane weight, the highest cane weight of 0.63 kg was recorded where crop was planted at 120 cm and 90 cm apart rows and sprayed with a combination of both macro and micronutrients (Table 1d). However, these were remained at par where crop was planted at 120 cm apart rows with all the foliar treatments. Similarly cane planted at 90 cm apart rows sprayed with micronutrients, combination of macro + micronutrients and control were also found at par with above treatments.

A significant effect of row spacing on the cane yield was noted. Significantly maximum cane yield of 96.67 t ha^{-1} was recorded in 120 cm apart rows. It was followed by cane planted at 90 cm apart rows (85.05 t ha^{-1}) which was at par with 75 cm apart rows (78.85 t ha^{-1}). Foliar application of nutrients also affect significantly and maximum cane yield was recorded where a combination of both macro and micronutrients was sprayed (95.53 t ha^{-1}). Spray of both macro and micronutrients separately were remained at par with each other (Table 1e).

Pol and brix (%) were not significantly affected by row spacing or foliar application of nutrients (Table 2a,b). Commercial Cane Sugar (%) showed significant differences in combinations of both row spacing and foliar application. Maximum CCS of 15.28% was recorded in at 90 cm spaced row without nutrient spray and it was followed by CCS 14.79% for F_1P_2 (Table 2c).

Regarding sugar recovery (%) neither row spacing nor foliar application of nutrients could reach a level of significance while interactive effect was significant. High sugar recovery of 14.41% was recorded in cane planted at 90 cm spaced rows without nutrient foliar application and it was followed by 13.90% where only macro nutrients were sprayed at same plant spacing while rest of the treatments showed significantly lower sugar recovery (Table 2d).

Table 1. Influence of row spacing and foliar application of nutrients on growth and yield of sugarcane.

Treatments	(a) Number of tillers				
	Control	Macro nutrients	Micro nutrients	Macro + Micro nutrients	Mean
75 cm apart row	14.59	16.48	16.48	16.89	16.09
90 cm apart row	15.37	15.87	16.67	17.04	16.29
120 cm apart row	15.56	15.83	15.83	16.57	15.95
Mean	15.17	16.05	16.32	16.83	ns

Treatments	(b) Cane length (cm)				
	Control	Macro nutrients	Micro nutrients	Macro + Micro nutrients	Mean
75 cm apart row	168.83	162.17	159.00	162.00	163.00
90 cm apart row	162.03	173.56	167.19	167.54	167.58
120 cm apart row	166.46	174.50	167.33	171.23	169.88
Mean	165.77	170.07	164.51	166.92	ns

Treatments	(c) Cane diameter (cm)				
	Control	Macro nutrients	Micro nutrients	Macro + Micro nutrients	Mean
75 cm apart row	2.27	2.26	2.29	2.38	2.31 b
90 cm apart row	2.37	2.43	2.45	2.59	2.46 a
120 cm apart row	2.43	2.59	2.47	2.62	2.53 a
Mean	2.36 b	2.43 b	2.41 b	2.53 a	

LSD for Row Spacing = 0.08, LSD for Foliar spray = 0.09

Treatments	(d) Weight per stripped cane (kg)				
	Control	Macro	Micro nutrients	Macro + Micro	Mean
75 cm apart row	0.49 b	0.46 c	0.44 b	0.55 b	0.48 b
90 cm apart row	0.51 ab	0.55 b	0.55 a	0.62 a	0.55 a
120 cm apart row	0.55 a	0.66 a	0.57 a	0.63 a	0.60 a
Mean	0.51	0.55	0.52	0.60	

LSD for Row spacing = 0.06, LSD for Interaction = 0.05

Treatments	(e) Stripped cane yield (t ha^{-1})				
	Control	Macro	Micro nutrients	Macro + Micro	Mean
75 cm apart row	73.99	76.81	72.32	92.30	78.85 b
90 cm apart row	77.39	84.99	83.52	94.29	85.05 b
120 cm apart row	83.58	100.09	99.03	100.01	96.67 a
Mean	79.98 c	87.29 b	84.95 b	95.53 a	

LSD for Foliar spray = 3.42, LSD for Row spacing = 10.00
Any two means not sharing a letter in common differ significantly at 5% probability level (LSD)

Table 2. Influence of row spacing and foliar application of nutrients on quality traits of sugarcane

Treatments	(a) Brix (%)				
	Control	Macro nutrients	Micro nutrients	Macro + Micro nutrients	Mean
75 cm apart row	20.46	21.11	21.31	20.71	20.89
90 cm apart row	22.32	21.92	21.87	21.93	22.01
120 cm apart row	21.43	22.13	21.98	21.78	21.83
Mean	21.41	21.72	21.72	2147	ns
Treatments	**(b) Pol (%)**				
	Control	**Macro nutrients**	**Micro Nutrients**	**Macro + Micro nutrients**	**Mean**
75 cm apart row	18.18	18.76	18.89	18.39	18.56
90 cm apart row	20.00	19.44	19.23	18.71	19.37
120 cm apart row	18.88	19.05	19.01	19.34	19.07
Mean	19.02	19.08	19.04	18.85	
Treatments	**(c) Commercial cane sugar (%)**				
	Control	**Macro nutrients**	**Micro nutrients**	**Macro + Micro nutrients**	**Mean**
75 cm apart row	13.86 b	14.29 a	14.37 a	14.02 a	14.14
90 cm apart row	15.28 a	14.79 a	14.56 a	14.01 b	14.66
120 cm apart row	14.31 b	14.22 a	14.24 a	14.73 a	14.37
Mean	14.48	14.43	14.39	14.25	
LSD for Row Spacing = 0.08, LSD for Foliar spray = 0.09					
Treatments	**(d) Sugar recovery (%)**				
	Control	**Macro nutrients**	**Micro nutrients**	**Macro + Micro nutrients**	**Mean**
Treatments	Control	Macro	Micro nutrients	Macro + Micro	Mean
75 cm apart row	13.86 b	14.29 a	14.37 a	14.02 a	14.14
90 cm apart row	15.28 a	14.79 a	14.56 a	14.01 b	14.66
120 cm apart row	14.31 b	14.22 a	14.24 a	14.73 a	14.37
Mean	14.48	14.43	14.39	14.25	

LSD for Interaction = 0.6656
Any two means not sharing a letter in common differ significantly at 5% probability level (LSD)

Leaf area index (Fig. 1) varied among various row spacings and foliar applications from April to February. However, it was significantly maximum where crop was planted at 120 cm apart rows, followed by 90 cm apart rows and the minimum was in 75 cm apart rows, throughout the season. Leaf area index was significantly maximum in the treatment F_3, where macro + micro nutrients were sprayed and it was minimum in control.

Periodic data regarding LAD of different row spacings and foliar applications is depicted in Fig. 1. Regarding row spacing, LAD was non significant among different row spacings during the whole period of the crop. However, it remained higher in 120 cm spaced rows. On the other hand, LAD was significantly affected by different foliar applications of the nutrients. The combined spray of both macro and micro nutrients showed maximum LAD which was followed by F_2, where micro nutrients were applied and both were at par with each other.

Wider row spacings of 90 and 120 cm was better among the row spacings in case of total dry matter production where total dry matter was significantly higher than 75 cm apart rows (Fig. 1). Application of both macro and micro nutrients was superior with respect to DM production followed by application of micro nutrients, Fe and Zn.

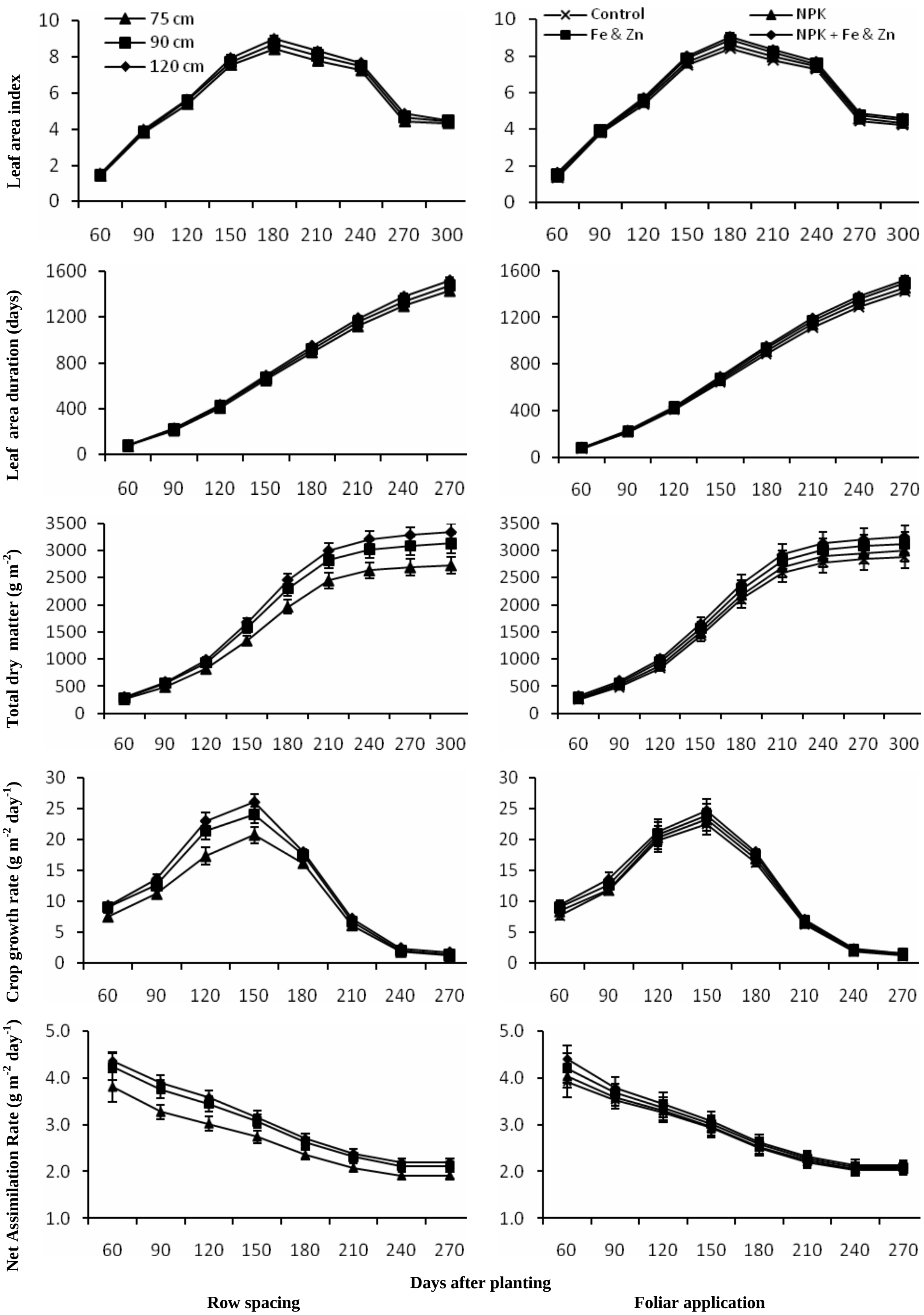

Fig. 1. Different growth and yield related parameters as affected of different row spacings and foliar application of nutrients.

Crop growth rate and NAR were significantly higher in wider row spacings (Fig. 1). Crop growth rate differed significantly among row spacings during the months of July, August and September. It was significantly higher at 120 cm spaced rows followed by 90 cm spaced rows. Row spacing of 75 cm was failed to become at par with both wider rows in case of CGR. Among various foliar applications, CGR was significantly affected during the whole crop season.

Discussion

Non significant difference in number of canes m^{-2} and cane length in cm was recorded. At early growth stage, crop canopy is less developed and there is no problem of sunlight penetration which might be a reason for same number of tillers. Non significant difference in cane length might be due to varietal character of test variety which may recover any stress under favorable conditions. Higher cane weight recorded in row spacing of 120 cm may be due to the fact that wider spacing had improved the efficiency of plants to use the nutrients, space and light. The results confirm the findings of those reported by El-Geddawy *et al*., (2002) who obtained more stalk weight in wider row spacing. In general, it is transparent from the interactive values that the trend of the crop to produce stripped canes with more weight was positive when grown in 120 cm apart rows with all the nutrition treatments. It might be due to utilization of the nutrition more effectively at wider row spacings where competition for nutrition, space etc. was less than at closer.

As a consequence of more cane diameter and cane weight, stripped cane yield was significantly higher in wider spacings than narrow one. These findings were in agreement with that reported by Hossain *et al*., (1999) who also observed more cane yield in 120 cm apart dual row spacing. Foliar application of macro + micro nutrients or micro nutrients alone significantly improved the yield. This is due to the fact that all these nutrients play an important role in plant growth and development. However, in case of micro nutrients, the significance of these elements is again proved and also they played significant role in improving yield. Findings by Haung & WengFung (2004) are also similar to our results.

Interactive effect of row spacing and foliar application on quality parameters of cane such as CCS and sugar recovery (%) was found significant. It is clear that application of nutrients improves CCS (%) in cane juice at wider spacings. Khan *et al*., (2005) also found that with the increase in macro nutrients in the growing media up to a certain level, CCS (%) was improved. Similarly Abro *et al*., (2004) also found that cane brix, pol and CCS percentages had positive relationship with all the micro nutrients. Moreover, pol and brix % age was not affected significantly in this study. Similar results were reported by Tej *et al*., (2006) and Phogat *et al*., (1986), who reported that row spacing had non significant effect on quality traits.

Leaf area index directly depends upon proper spacing and nutrition availability. The variable LAI in different row spacings is ascribed to better leaf development. Greater LAI in 120 cm apart rows than the other row spacings was due to availability of proper spacing which resulted in greater leaf area per plant and more leaf area duration. These results are contradictory to those of Alonso & Scadaliaris (1988), who reported that maximum LAI was noted where crop was planted at 40 cm apart rows and it was more in rows with consistent inter row spacings than in rows with alternate inter row spacings. Roodagi *et al*., (2001) reported non significant effect of planting method on LAI. Leaf area index was also maximum in F_3 where macro + micro nutrients were sprayed. Maximum LAI in F_3 might be due the fact that both macro and micro nutrients play a vital role in the development of leaf and the growth of the crop. Tej *et al*., (2006) also found that with increasing fertilization, LAI was increased. The variability in LAD is attributed to the variable LAI in different row spacings. Total dry matter production was also recorded significantly higher in case of wider row spacing and foliar application of a combination of macro and micro nutrients. The reason might be that in both the cases plant used the nutrients efficiently as a result of which more assimilates were produced resulting in more TDM.

Various fluctuation of CGR for row spacing might be due the variability of various parameters like LAI and LAD. These results are in accordance with those of Singh *et al*., (2001) who reported more CGR in wider row spacing (90 cm) among the different row spacings. However, Tej *et al*., (2006) reported non significant differences among different row spacings for CGR. Increase in CGR in combination of macro and micro nutrients is due to the increase in nutrition of the crop. Tej *et al*., (2006) also found that with increasing nutrition, CGR was increased.

Net assimilation rate was significantly maximum in plots, where crop was planted at 120 and 90 cm apart rows. These results are in accordance with those of Singh *et al*., (2001), who reports more NAR in wider row spacing among the different treatments. Maximum NAR was observed in plants which were treated with macro and micro nutrients, although at later stages NAR was remained at par with all foliar applications. It might be due to the reason that every nutrient is required for the metabolism within the plant in a balanced amount (Epstein & Bloom, 2005). Tej *et al*., (2006) also found that with increasing fertilization, NAR was increased.

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