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PHYSIOLOGICAL RESPONSE OF AUTUMN PLANTED SUGARCANE TO PLANTING GEOMETRY AND NUTRIENT MANAGEMENT ON DIFFERENT SOILS UNDER ARID CONDITIONS

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ABSTRACT

In a field trial physiological response of sugarcane cultivar HSF 240 to different nutrient doses like F_1=0-0-0, F_2=100-100-100, F_3=150-150-100, F_4=200-200-100 and F_5= 250-200-100 kg NPK ha^{-1} and planting patterns G_1=60cm, G_2=75cm single row planting pattern, G_3=30/90cm and G_4=30/120cm spaced paired row strip planting pattern was determined at the research area of the Gomal University Rukh Bibi campus Dera Ismaiel Khan and Main Line Lower Land Reclamation Research Station Bhakkar during 2003-04 and 2004-05. The experiment was laid out according to randomized complete block design (RCBD) with a split plot arrangement having four replications. The analysis of pooled data of D.I Khan and Bhakkar revealed that different nutrient doses influenced all the physiological traits to a significant level. The maximum Crop growth rate (CGR), Leaf area index (LAI), Leaf area duration (LAD) and Net assimilation rate (NAR), were recorded at a fertilizer level of 250-200-100 kg NPK ha^{-1} however CGR, LAI, LAD, NAR, were not statistically different from those recorded at 200-200-100 kg NPK ha^{-1} during both years. The maximum CGR, LAI, LAD, NAR were recorded in planting pattern of 30/90cm spaced paired row strip planting pattern followed by 75cm and 60cm single row planting pattern and was minimum in 30/120cm spaced paired row strip planting pattern where as LAI and NAR were non significant in all planting patterns during both years. The maximum CGR, LAI, LAD, NAR were recorded in 250–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern and these were also significantly higher than all other inter-active treatments and minimum in control x 30/120 cm spaced paired row strip planting pattern during both years. Where as CGR, LAI, LAD, NAR, were at par with 200–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern during both years. Therefore it is recommended that under arid conditions on Silt clay and sandy loam soils optimum LAI, LAD, CGR and NAR, were obtained from nutrient dose of 200–200-100 kg NPK ha^{-1} and 30/90cm spaced paired row strip planting pattern.

Key words: *Saccharum officinarum L.*, NPK management, planting geometry, agro-physiological parameters, autumn planted sugarcane, Pakistan

INTRODUCTION

In Pakistan the average cane yield is much lower than the production potential of our existing sugarcane cultivars due to improper nutrient management and planting geometry. Sugarcane is a along duration crop and its 125t ha^{-1} depletes an average 83 kg N, 37 kg P_2O_5, 168 kg K_2O (Yadava, 1991). Photosynthesis is the most practical way of harvesting solar energy. Sugarcane is considered to be the most efficient converter of solar energy to stored food energy in the form of carbohydrates. According to an estimate for every calorie of energy invested in sugarcane cultivation, about five calories of energy are harvested in its use able form i.e. in the form of sugar (Yadava, 1991). Therefore an adequate and balanced supply of all these nutrients in the effective root zone of crop is essential for obtaining sustainable cane yield (Ingawale *et al*.1992).

Colazo and Armas (1985) reported that crop growth rate and net assimilation rate increased when K was applied in addition to N. Lal (1991) found greater leaf area index at 225 kg nitrogen ha^{-1} as compared to 175 and 150 kg N ha^{-1}. Ali (1999) recorded significantly higher leaf area index, leaf area duration and crop growth rate with the use of 250-100-100 kg NPK ha^{-1} whereas the maximum net assimilation rate was obtained at 100-0-0 kg NPK ha^{-1}.

Efficient interception of radiant energy coming to crop surface requires adequate and uniformly distributed leaf area to give the maximum ground cover. This is achievable by proper orientation of plants over the land surface and their suitable nutrient management. Watson (1947) proposed leaf area index as the best measure for the capacity of crop for producing dry matter. Photosynthesis, respiration, dry matter accumulation and the growth could be expressed as a function of leaf area index. The leaf area index had been used to estimate light interception (Yadav, 1982). Mali (1980) and Singh and Singh (1984) reported that an increase in inter-row spacing from 60cm to 90cm increased leaf area index of sugarcane. Mali and Singh (1988) planted eight sugarcane cultivars in

60cm, 90cm and 120 cm spaced rows. They reported significant effect of both row spacing and cultivars on leaf area index, leaf area duration and crop growth rate. Ali (1999) observed the significant effect of planting pattern on net assimilation rate.

Physiological characters like leaf area index, leaf area duration, crop growth rate and net assimilation rate in crop communities responsible for higher yield, need investigation so that parameters for establishing quality cane tonnage could be ascertained and incorporated in future studies. It is specially mentioned that most of above mentioned work is done on spring planted sugar cane crop and autumn planted crop is totally neglected, therefore present study is designed to determine the impact of different nutrient doses and planting patterns on the physiological traits of autumn-planted sugarcane under the edaphic and agro climatic conditions of the remotest areas of two provinces of Pakistan which are Dera Ismaiel Khan situated at (031^0 28.40 N ^{0} and 071^0 58.54 E ^{0}) with Silt clay soil in NWFP and Bhakkar situated at (031^0 36.365 N ^{0} and 071^0 9.844 E ^{0}) with sandy loam soil in Punjab.

MATERIALS AND METHODS

The study was conducted at the research area of Rukh Bibi campus of Gomal University Dera Ismaiel Khan and Main Line Lower Land Reclamation Research Station Chak No 37 TDA (Thal Development Authority) Bhakkar during 2003-04 and 2004-05. The nutrient doses under study were F_1=0-0-0, F_2=100-100-100, F_3=150-150-100, F_4=200-200-100 and F_5 =250-200-100 kg NPK ha^{-1}.The planting patterns comprised of G_1=60cm, G_2=75cm spaced single row planting pattern and G_3=30/90cm, G_4=30/120cm spaced paired row strip planting pattern while the seed was used at the rate of 70,000 double-budded setts ha^{-1}. Cane cultivar "HSF 240" was used as test crop. The experiment was laid out in a randomized complete block design (RCBD) with a split plot arrangement keeping the nutrient doses in main plots and planting patterns in sub-plots. The net plot size was 24m^2 with four replications. The crop was planted during the 1st week of September and harvested in first week of December next year during both years at both locations. All the phosphorus, potassium and 1/4 of total nitrogen were applied at the time of seed bed preparation while remaining nitrogen was applied in two equal splits each at completion of germination and at the start of cane formation. The crop was kept free of weeds and irrigated when it was needed .All other agronomic practices were kept normal and uniform for all the treatments. Observations on crop growth rate, leaf area index, leaf area duration, and net assimilation rate, were recorded using standard procedures. The data was analyzed statistically using Fisher's analysis of variance technique and LSD test at 0.05 percent level of probability was employed to compare the differences among the treatment means (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Crop growth rate

According to Gardner *et al*. (1988), crop growth rate (CGR) is the gain in weight of a community of plants per unit of land and of time. Analysis of pooled data of both locations D.I Khan and Bhakkar regarding CGR shown in Table-1 revealed that CGR was significantly different under different nutrient doses. Maximum CGR was recorded (8.02 and 8.23 g m^{-2} day^{-1})during 2003-04 and 2004-05, respectively in 250- 200-100 kg NPK ha^{-1} (F_5)and was at par with 200-200-100 kg NPK ha^{-1} (F_4)followed by 150-150-100 kg NPK ha^{-1} (F_3), 100-100-100 kg NPK ha^{-1}(F_2) and minimum (2.75 and 2.82 g m^{-2} day^{-1})during 2004 and 2005,respectively was recorded in control(F_1) It was observed that 62.64, 62.17, 49.91, 41.74% and 62.75, 62.40, 51.13 and 42.57% higher CGR was recorded during 2003-04 and 2004-05 in F_5, F_4, F_3, and F_2, then F_1, respectively indicating that optimum CGR at 200-200-100 kg NPK ha^{-1} may be due to increased nutrient availability which increased photosynthetic efficiency and improved cane growth and alone increase in N has no significant effect on CGR. Ali (1999) reported that CGR was affected significantly by different fertilizer levels and the maximum CGR was recorded at 250-100-100 kg NPK ha^{-1}.

The CGR was significantly different under various planting patterns. The maximum CGR (5.95 and 6.15 g m^{-2} day^{-1}) during 2003-04 and 2004-05, respectively was recorded in 30/90cm spaced paired row strip planting pattern (G_3) followed by 75cm (G_2) and 60cm single row planting pattern (G_1) and minimum (5.05 and 5.24 g m^{-2} day^{-1}) during 2003-04 and 2004-05, respectively in 30/120cm paired row strip planting pattern (G_4). It was observed that 15.13, 10.93 6.48% and 14.80, 10.58 and 6.26% higher CGR during 2003-04 and 2004-05, respectively in G_3, G_2 and G_1 respectively was recorded than G_4. The higher CGR at 30/90cm spaced paired row strip planting pattern was probably due to improved air circulation and light penetration which improved photosynthetic efficiency and too much increase in inter strip spacing as in 30/120cm paired row strip planting pattern number of plants per unit area had to increase to maintain optimum plant population, due to which inter plant competition increased causing adverse effects on CGR. Mali and Singh (1988b) and Gill (1995) stated a significant effect of various planting patterns on cane CGR.

Interactive effect of different nutrient doses and planting patterns CGR was highly significant. Maximum CGR (8.02 and 8.23 g m^{-2} day^{-1}) during 2003-04 and 2004-05,respectivly was recorded in 250–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_5xG_3) followed by 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_4xG_3) and was minimum (2.64 and 2.66 g m^{-2} day^{-1})during 2003-04 and 2004-05,respectivly in control x 30/120 cm spaced paired row strip planting pattern (F_1xG_4). The higher CGR in (F_5xG_3) may be due to complimentary effect of increased nutrient availability and improved air circulation and light penetration which improved photosynthetic efficiency and resulted in increased CGR.

Leaf area index

The analysis of pooled data of both locations Dera Ismaiel Khan and Bhakkar regarding leaf area index (LAI) in Table-1 revealed that the cane leaf area index was significantly affected by different nutrient doses and was the highest (6.67 and 6.54) during 2004 and 2005,respectively in 250-200-100 kg NPK ha^{-1} (F_5) which was at par with 200-200-100 kg NPK ha^{-1} (F_4) and 150-150-100 kg NPK ha^{-1} (F_3), followed by 100-100-100 kg NPK ha^{-1} (F_2)and was the lowest (4.88 and 4.75) during 2003-04 and 2004-05,respectively. It was observed that 26.84, 26.62, 24.34, 22.42% and 27.37, 27.26, 25.31 and 21.88% higher LAI during 2003-04 and 2004-05 was recorded in F_5, F_4, F_3, F_2 respectively than F_1. It showed that increase in Nitrogen and Phosphorus level more than 150 kg ha^{-1} had no significant effect on LAI.

Non significant effect of LAI was recorded in different planting patterns. Alonso and Scandaliaris (1988) reported that LAI was not influenced by row spacing in any of the crops. Interactive effects of planting patterns and nutrient doses on LAI were non-significant except in Interactions of (F_1) control with all planting patterns.

Leaf area duration

The analysis of pooled data of D.I Khan and Bhakkar regarding leaf area duration (LAD) shown in Table-1 revealed that cane leaf area duration was significantly different under different nutrient doses and planting patterns. LAD was maximum (891.57 and 904.81 days) during 2003-04 and 2004-05,respectivly in 250-200-100 kg NPK ha^{-1} (F_5) but it was at par with 200-200-100 kg NPK ha^{-1} (F_4) and significantly superior to rest of the fertilizer levels and was minimum (478 and 476.83 days) during 2004 2005,respectivly in control (F_1) indicating that optimum LAD at 200-200-100 kg NPK ha^{-1} may be due to increased nutrient availability which increased photosynthetic efficiency and improved cane leaf senescence and alone increase in N has no significant effect on LAD. Ali (1999) reported that maximum LAD of 984 days was recorded in 250-100-100 kg NPK ha^{-1}.

LAD was affected significantly by different planting patterns and was maximum (817.93 and 829.20 days) during 2003-04 and 2004-05, respectively in 30/90cm paired row strip planting pattern (G_3) followed by 75cm (G_2), and 60cm single row planting pattern (G_1) and was minimum (749.32 and 758.56 days) during 2003-04 and 2004-05, respectively in 30/120cm paired row strip planting pattern (G_4). It was observed that 8.39, 5.17, 1.07% and 8.52, 5.36 and 1.7% higher LAD during 2003-04 and 2004-05, respectively was recorded in G_3, G_2, and G_1 respectively than G_4. The higher LAD at 30/90cm spaced paired row strip planting pattern was probably due to improved air circulation and light penetration which improved photosynthetic efficiency and too much increase in inter strip spacing as in 30/120cm paired row strip planting pattern number of plants per unit area had to increase to maintain optimum plant population, due to which inter plant competition increased causing adverse effects on LAD. Mali and Sing (1988) [b] has also reported significant difference in LAD in different row spacing.

Interactive effect of different nutrient doses and planting patterns on LAD was highly significant. Maximum LAD (946.24 and 964.93 days) during 2003-04 and 2004-05,respectivly was recorded in 250–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_5xG_3) which was at par with 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_4xG_3) and was minimum (469.68 and 462.96 days) during 2003-04 and 2004-05,respectivly in control x

30/120cm spaced paired row strip planting pattern (F_1xG_4). The optimum LAD in (F_4xG_3) may be due to complimentary effect of increased nutrient availability and improved air circulation and light penetration which improved photosynthetic efficiency and resulted in improved cane leaf area duration.

Net assimilation rate

Net assimilation rate (NAR) is the net gain of photosynthetic assimilates per unit of leaf area and time (Gardner *et al*., 1988). The analysis of pooled data of both locations D.I Khan and Bhakkar regarding NAR shown in Table-1 revealed that NAR was significantly different under different nutrient doses and was maximum (1.85 and 1.91 g m^{-2} day^{-1})during 2003-04 and 2004-05,respectively in 250- 200-100 kg NPK ha^{-1} (F_5)but it was at par with 200-200-100 kg NPK ha^{-1} (F_4)followed by 150-150-100 kg NPK ha^{-1} (F_3), 100-100-100 kg NPK ha^{-1} (F_2) and was minimum in control(F_1). It was observed that 29.73, 29.35, 11.56, 2.26% and 30.37, 30, 19.39, and 4.32% higher NAR higher NAR during 2004-2005, respectively in F_5, F_4, F_3, F_2 respectively than control F_1. The increased NAR at higher NPK dose was ascribed to increased nutrient availability and complementary effect of N, P, and K which resulted in higher CGR, LAI and LAD. It was also indicated that alone increase in N has no significant effect on NAR.

The data regarding NAR of different planting patterns was non significant. Interactive effects of different planting patterns and nutrient doses were significantly different. Maximum NAR (1.91 and 1.95 g m^{-2} day^{-1})during 2003-04 and 2004-05,respectivly was recorded in 250–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_5xG_3) which was at par with 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_4xG_3) and was minimum (1.26 and 1.3 g m^{-2} day^{-1}) during 2003-04 and 2004-05,respectivly in control x 30/120 cm spaced paired row strip planting pattern (F_1xG_4). It was also observed that optimum NAR in (F_4xG_3) was due to complimentary effect of increased nutrient availability and improved air circulation and light penetration which enhanced the photosynthetic efficiency which resulted in accelerated NAR.

Table-1 Physiological response of autumn planted sugarcane to nutrient management and planting geometry on different soils under arid conditions

Treatments	CGR ($g\ m^{-2}\ day^{-1}$)		LAI		LAD (days)		NAR ($g\ m^{-2}\ day^{-1}$)	
	Pooled data of D I Khan and Bhakkar							
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
(A)-N : P : K Fertilizer nutrient Doses (kg ha^{-1})								
F_1 = 0 : 0 : 0	2.75d	2.82d	4.88c	4.75c	478.00d	476.83d	1.30c	1.33d
F_2 =100:100:100	4.72c	4.91c	6.29b	6.08b	795.86c	809.67c	1.33c	1.39c
F_3 =150:150:100	5.49b	5.77b	6.45ab	6.36ab	837.35b	856.44b	1.47b	1.65b
F_4 =200:200:100	7.27a	7.50a	6.65ab	6.53ab	888.78a	903.36a	1.84a	1.90a
F_5 =250:200:100	7.36a	7.57a	6.67a	6.54a	891.57a	904.81a	1.85a	1.91a
LSD	0.22	0.22	0.38	0.38	4.16	4.16	0.06	0.06
(B)-Planting patterns (G)								
G_1 =60cm	5.40c	5.59c	6.10a	6.00a	757.40c	771.64c	1.57a	1.67a
G_2 =75cm	5.67b	5.86b	6.23a	6.12a	790.19b	801.48b	1.58a	1.66a
G_3 =30/90cm	5.95a	6.15a	6.34a	6.22a	817.93a	829.20a	1.60a	1.67a
G_4 =30/120cm	5.05d	5.24d	6.07a	5.95a	749.32d	758.56d	1.50a	1.63a
LSD	0.2	0.2	0.34	0.34	3.72	3.72	0.06	0.06
(C)-F x G								
F_1 x G_1	2.69l	2.77m	4.82b	4.73b	466.78m	472.69m	1.30fgh	1.34i
F_1 x G_2	2.78l	2.88m	4.89b	4.77b	481.75l	482.53l	1.30fgh	1.35hi
F_1 x G_3	2.90l	2.95m	4.96b	4.81b	493.79k	489.14l	1.32fgh	1.34i
F_1 x G_4	2.64l	2.66m	4.83b	4.68b	469.68m	462.96n	1.26gh	1.30i
F_2 x G_1	4.62jk	4.85kl	6.22a	6.13a	779.17i	796.49j	1.33fgh	1.65de
F_2 x G_2	4.93ij	5.07jk	6.34a	6.23a	809.13h	821.49i	1.37efgh	1.63de
F_2 x G_3	5.08hi	5.22jk	6.41a	6.29a	825.39g	838.80h	1.38defg	1.60ef
F_2 x G_4	4.27k	4.48l	6.19a	6.08a	769.74j	781.89k	1.25h	1.73cd
F_3 x G_1	5.39gh	5.66hi	6.38a	6.29a	818.31g	837.63h	1.48de	1.49fg
F_3 x G_2	5.61fg	5.92gh	6.41a	6.40a	847.18f	866.86ef	1.49de	1.49fg
F_3 x G_3	5.83f	6.15g	6.60a	6.48a	876.56c	889.42c	1.50d	1.50fg

F_3 x G_4	5.11hi	5.33ij	6.34a	6.27a	807.34h	831.84h	1.42def	1.47gh
F_4 x G_1	7.10d	7.30de	6.53a	6.43a	856.55e	875.11de	1.87ab	1.92ab
F_4 x G_2	7.48cd	7.67cd	6.70a	6.59a	902.73b	918.26b	1.86abc	1.92ab
F_4 x G_3	7.94ab	8.19ab	6.86a	6.75a	947.66a	963.71a	1.89a	1.94a
F_4 x G_4	6.56e	6.82f	6.49a	6.38a	848.17f	862.14fg	1.74c	1.81bc
F_5 x G_1	7.19cd	7.37cd	6.57a	6.43a	866.18d	876.30d	1.87ab	1.93ab
F_5 x G_2	7.56bc	7.78bc	6.73a	6.59a	910.17b	918.26b	1.87ab	1.92ab
F_5 x G_3	8.02a	8.23a	6.86a	6.75a	946.24a	964.93a	1.91a	1.95a
F_5 x G_4	6.66e	6.89ef	6.51a	6.35a	851.68ef	853.96g	1.76bc	1.84abc
LSD	0.44	0.44	0.75	0.75	8.33	8.33	0.12	0.12

Means followed the same letter in a column do not differ significantly at 5 % level of probability

CONCLUSION

It is concluded that under arid conditions on Silt clay and sandy loam soils optimum net assimilation rate was obtained in the interaction of 200–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern. The plating pattern of 30/90cm paired row strip planting had few advantages over other planting patterns like, it facilitates interculture and earthing up of the crop without damaging the roots, 50% reduction in the number of inter-strip ditches/furrows, thus conserving irrigation water and saving almost 50% in labor and time required for earthing up, allows efficient and expeditious interculture and earthing up with tractor or bullock-drawn implements, permits systematic planting and handling of intercrops without affecting the associated cane crop. Moreover, planting of the main and intercrops in separate and independent strips not only reduces intercrop competition, but also enables the grower to meet the varying fertilizer requirements, growth patterns, and planting times of different crops, facilitates easy application of herbicides since the strips are well spaced, prevents lodging in case of unusual wind or rain since the strips provide plant support to each other, improves the air circulation and light penetration which enhances the photosynthetic efficiency of plants and reduces crop damages from trampling by wild animals looking for a space to rest.

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