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Bio-Economic Response of Autumn Sugarcane to Soil Variation, NPK Management and planting Geometry under Arid Climate

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Abstract: ***Autumn sugarcane crop is commonly fertilized @ 175-60-60 and 300-175-125 NPK kg ha^{-1} in sandy loam and silty clay soils, respectively. Whether these fertilizer doses are sufficient or otherwise for the fulfillment of this sugarcane crop demand is yet to be established. A comprehensive study (2005-06 to 2007-08) was conducted to identify the optimum NPK dose in sandy loam and silty clay soils. This study was conducted on autumn sugarcane cv. HSF 240 at two different locations, Land Reclamation Research Station 37/TDA, Bhakkar and Gomal University Dera Ismail Khan, Pakistan. The experiments were laid out according to randomized complete block design with factorial arrangement. The trial was replicated four times with net plot of 24 m^2.Five NPK doses i.e. F0 (0-0-0), F1 (100-100-100), F2 (150-150-100), F3 (200-200-100) and F4 (250-200-100) kg ha^{-1}alongwith four planting arrangements i.e. G1 (60cm), G2 (75cm) single row planting patterns, G3 (30/90cm) and G4 (30/120cm) spaced paired row strip planting patterns were tested. Statistical analysis of three years pooled data showed that NPK doses affected the sugar yield contributing parameters, significantly. Maximum shoot dry weight (1900.8 & 1949.2 g m^{-2}) was recorded in F4 × G3, while minimum in F0×G4 (624.8 & 629.2 g m^{-2}) on sandy loam and silty clay soil, respectively. Maximum sugar yield (14.81 & 15.52 t ha^{-1}) was recorded in F4×G3 and minimum (3.66 & 4.03t ha^{-1}) in F0×G1 on sandy loam and silty clay soils. Maximum sugar recovery (11.5 and 10.90%) was recorded in the treatment interaction of F0×G4 and minimum (7.67 and 8.64%) in F4×G1 on sandy loam and silty clay soils. Maximum FUE (289.4 & 290.2 kg kg^{-1}) was obtained in treatment interaction of F3×G3 on both soils. It was concluded that maximum sugar yield, BCR and FUE from nutrient dose of 200–200-100 kg NPK ha^{-1} cum 30/90cm spaced paired row strip planting can be harvested in sandy loam and silty clay soils in arid climate. Sugar recovery percentage was recorded maximum in interaction of control and 30/120cm spaced paired row strip planting. Nutrient application of 200-200-100 NPK kg ha^{-1} having planting geometry of 30/90 cm paired row strips planting was proved optimum for maximum sugar yield.***

Keywords: Autumn Sugarcane, *Saccharum oficinarum*, NPK, Soil texture, planting geometry.

1. Introduction

Sugarcane *(Saccharum oficinarum* L.) is considered a huge tropical, long duration, nutrient loving plant as it consumes 83 kg N, 37 kgP_2O_5, and168 kg K_2O for production of 125 t ha^{-1} biomass (Yadava, 1991). Therefore an adequate and balanced supply of all inputs in the effective root zone of crop is essential for obtaining sustainable cane yield. Sugarcane is cultivated in Pakistan on an area of 0.99 m ha with average cane yield of 56.0 t ha^{-1} (MINFAL 2010-11). Country average yield is much lower as compared with sugarcane production other countries of the world (GOP 2010). Lower cane yield in sugarcane is due to improper nutrient management and planting geometry (Saggu *et al.* 2010). Afghan (1996) reported that application of bio-compost and NPK gave significantly higher shoot dry weight (SDW).Application of 250-100-100 kg NPK ha^{-1}gave the highest SDW (Ali, 1999). NPK accumulation and uptake in plants were higher at 225:112:168 NPK kg ha^{-1} (Soomro *et al*. 2014). Ali (1999) reported that N application decreased the sucrose contents in cane juice however, Rani *et al.* (1989) concluded that addition of N in combinations with P and K improved the sucrose consents as against with only N application. On the contrary, Ayub *et al.* (1999), Ramesh and Varghese (2000) and Shafshak *et al.* (2001) proposed that sucrose contents were not affected significantly by fertilizer application. The economic yield is determined by the capability of plant to produce photosynthates and their distribution to economically valuable plant parts. In order to harvest the maximum benefits of soil and environmental resources, it is necessary to lay out crop in such a pattern that there must be less inter plants competition for essential growth elements.

Sugarcane planting in widely spaced rows (Kathirisan and Narayanasmy, 1991) had higher sucrose contents in comparison with narrow spaced rows planting. However, Vains *et al*. (2000) reported that sucrose content in cane juice was not affected significantly by different spatial arrangements and plantation methods. El-Geddawy *et al*. (2002) obtained significantly higher cane yield at the row spacing of 100cm than 120 or 140cm spaced rows in the 1st. ratoon crop in Egypt, whereas Singh and Prasad (2006) recorded significantly higher cane yield at 45cm spacing followed by 60cm and 75cm in ratoon crop.

Sugarcane crop research has been confined mainly to spring planting while autumn sugarcane was left out of research

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arena. Therefore it was considered outstanding obligation to establish sound information on impact of NPK doses, planting geometry and soil texture in autumn sugarcane in two different agro ecological pockets of unexplored areas of Pakistan. The objective of this study was to enhance the capability of plant to produce photosynthates and their mobilization to economically valuable plant parts through proper crop management.

2. Materials and Methods

Three year studies (2005-06 to 2007-08) were conducted on autumn sugarcane cultivar (HSF 240) at two sites in Pakistan. First location was Land Reclamation Research Station, Chak No. 37/ TDA (sandy loam soil) Bhakkar (031^0-34-54 N and 071^0–03 – 33 E) Punjab and second site was Research Area (silty clay soil) of Gomal University Dera Ismail Khan Kyber Pakhtunkhwa (031^0 -38-31N and 070^0 – 56 – 49 E). Physico-chemical properties of two different soil types as tested pre-planting and post harvest during each crop season/year are presented in Table 1 and 2.

Table 1: Characteristics of soils before sugarcane planting from 2005-06 to 2007-08

Location	*Description*	*Characteristic (unit)*	*2005-06*	*2006-07*	*2007-08*
Bhak Kar	Soil Texture	class	Sandy Loam	Sandy Loam	Sandy Loam
	N	%	0.044	0.049	0.046
	P	ppm	3.55	4.75	4.16
	K	ppm	55	60	57.4
	Field capacity	% by volume	15.71	17.97	16.8
	Bulk density	gcm^{-3}	1.4	1.38	1.4
	Perm anent wilting point	%by volume	7.14	8.33	7.74
	pH	7 to 14	7.7	8	7.8
	Ec	dSm^{-1}	1	1	1.1
Dera Ismail Khan	Soil Texture	class	Silty clay	Silty clay	Silty clay
	N	%	0.03	0.04	0.035
	P	ppm	8	8.5	8.2
	K	ppm	80	92.5	84
	Field capacity	%by volume	23.85	24.24	24.05
	Bulk density	gcm^{-3}	1.3	1.35	1.31
	Perm anent wilting point	%by volume	11.54	11.852	11.68
	pH	-----	8	8.1	8.07
	Ec	dSm^{-1}	4.6	5.2	4.7

Table 2: Characteristics of soils after sugarcane harvesting from 2005-06 to 2007-08

Location	*Description*	*Characteristic (unit)*	*2005-06*	*2006-07*	*2007-08*
BHAKAR	Soil Texture	class	Sandy Loam	Sandy Loam	Sandy Loam
	N	%	0.032	0.038	0.036
	P	ppm	3.41	4.54	4.05
	K	ppm	54.3	58.89	59.24
	Field capacity	% by volume	15.71	17.97	16.8
	B ulk density	gcm^{-3}	1.4	1.38	1.4
	Perm anent wilting point	%by volume	7.14	8.33	7.74
	pH	7 to 14	7.6	7.88	7.67
	Ec	dSm^{-1}	1	1	1.1
DERA ISM A IL KHAN	Soil Texture	class	Silty clay Loam	Silty clay Loam	Silty clay Loam
	N	%	0.021	0.038	0.027
	P	ppm	7.89	8.33	9.12
	K	ppm	78	90.23	88
	Field capacity	%by volume	23.85	24.24	24.05
	Bulk density	gcm^{-3}	1.3	1.35	1.31
	Perm anent wilting point	%by volume	11.54	11.85	11.68
	pH	-----	7.91	7.87	8.13
	Ec	dSm^{-1}	4.6	5.2	4.7

Source: Soil and Water Testing Laboratory Directorate of Land Reclamation Punjab, Lahore, Pakistan

Five different NPK doses viz. F0 (0-0-0), F1 (100-100-100), F2 (150-150-100), F3 (200-200-100) and F4 (250-200-100) kg ha^{-1} and four planting patterns i.e. G1 (60cm), G2 (75 cm) spaced single row planting pattern, G3 (30/90cm) and G4 (30/120cm) spaced paired row strip planting were applied. The experiments were laid out in a randomized complete block design with split factorial arrangement. The net plot size was $24m^2$ with four replications. Crop was planted in different fields during the 1^{st}. week of September each year and harvested during the first week of November of the following year. The vegetative seed of sugarcane cultivar "HSF 240" was used @ 70,000 double budded setts ha^{-1}. All the phosphoric and potash fertilizers were applied pre-sowing while ¼th of total nitrogenous fertilizer was applied at the end of October and remaining was applied in each two equal splits at the end of March and

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April of the following years. The crop was kept free of weeds. All other agronomic requirements applied uniformly. Seventeen irrigations, each of 100 mm was applied to silty clay soil while 27 irrigations were provided to sandy loam soil to keep the field at 40 % available soil moisture depletion level. The observations on shoot dry weight and sugar yield, sugar recovery percentage, water use efficiency, fertilizer use efficiency and benefit cost ratio were recorded following standard procedures.

2.1. Soil Sampling and Determination of Moisture Content

Gravimetric procedure of soil moisture measurement (direct method) was applied to determine the water contents in the soil. Soil sampling for soil moisture measurement was carried out regularly on alternate days from sowing to the final irrigation (30 days before harvesting each year at both locations). The irrigations were applied at 40 % available soil moisture depletions in all treatments to bring back the field to field capacity. Maximum soil moisture extraction depth of 150 cm (83 % of active root zone) was followed as per procedure proposed by Black, 1957. Five samples were collected and blended. Composite soil samples were taken up to 150 cm at the depth intervals of 30 cm from randomly selected 5 sites in each plot for moisture determination. Available soil moisture contents on volume basis at 40 % depletion level were calculated as proposed by Penman, 1970, French and Legg, 1979) and presented in Table 3.

$$ASMDL = \frac{(Fc - Oi)}{(Fc - Pwp)}$$

Where ASMDL = Available Soil Moisture Depletion Level, Pwp = Permanent wilting point, Oi= Soil moisture content before irrigation in percent by volume, Fc = Field capacity in percent by volume.

Table 3: Critical soil water contents in percent on volume basis for different ASMD levels

Available soil moisture depletion level (ASMDL)	*Critical soil water contents % on volume basis (Oi) calculated by using the above formulae*					
	Sandy loam			*Silty clay*		
	2005-06	*2006-07*	*2007-08*	*2005-06*	*2006-07*	*2007-08*
40%ASMDL	12.3	14.1	13.5	18.9	19.3	19.2
Irrigation was applied to respective plots as soon as the desired available soil moisture depletion level reached in the soil in the crop root zone.						

2.2 Irrigation

Irrigation depth for 40 % ASMD level was determined by adopting the direct measurement method of crop water requirement as proposed by Rafiq 2001:

$$Dw = \frac{Drz(Fc - Oi)}{100}$$

Where Dw = Depth of water to be applied (mm), Drz= Depth of root zone (150 cm) i e 83% of effective root zone, Discharge of water applied to each treatment was determined with the help of a cut throat flume (8"× 3').

The time required to bring back the field to field capacity supply was calculated with the help of following equation (Rafiq 2001):

$$t = \frac{(d \times a)}{q}$$

Where t = time in minutes, d = depth of water cm, a = area m^2, q = discharge of irrigation water in liter/sec.
The observations on shoot dry weight and sugar yield were recorded using standard procedures. The sugar recovery percentage was calculated as per formula (CIMMYT manual, 1988) :

$$\text{Sugar Recovery (\%)} = \frac{S\,(J-M) \times Pol\,\% \times 0.65 \times 0.98}{J\,(S-M)}$$

Where S = Sugar 100%, J = Juice purity, M = Molasses purity = 35%, Pol% = Pol% juice (sucrose %), Juice extraction = 0.65, Boiling house efficiency = 0.98,
Water use efficiency was calculated as provided by Phulare and Upadhyay (1978).

$$WUE\ (kg\ mm^{-1}\ ha^{-1}) = \frac{\text{Stripped cane yield (kg)}}{\text{Water applied } (mm^{-1})}$$

Benefit cost ratio was calculated by using the following formula

$$BCR = \frac{\text{Total income}}{\text{Total expenditure}}$$ (CIMMYT manual, 1988)

Fertilizer use efficiency (FU E) was determined by the formula as proposed by Barber (1976).

$$FUE\ (Kg\ Kg^{-1}) = \frac{(St.C.\ Yield)_F\ (kg) - (St.C.\ Yield)\ C\ (kg)}{\text{Fertilizer nutrients applied (kg nutrients)}}$$

Where (St.C. yield) F = Stripped cane yield of fertilized crop, (St.C. Yield) C = Stripped cane yield of controlled crop
Shoot dry weight was calculated by taking five randomly selected cane shoots from each treatment at 30 days interval. These shoots were sun dried and then oven dried at 70 $C^0$for 72 hours, to a constant dry weight. Dry weight per plant was converted to total dry weight m^{-2} by multiplying it with stalk populationm^{-2}. Sugar yield was calculated by multiplying stripped cane yield (t ha^{-1}) with sugar recovery percentage.
The data were analyzed statistically using Fisher's analysis of variance technique and Least Significant Test at 0.05 level was used to compare the differences among the treatment means (Steel *et al.*, 1997).

3. Results and Discussions

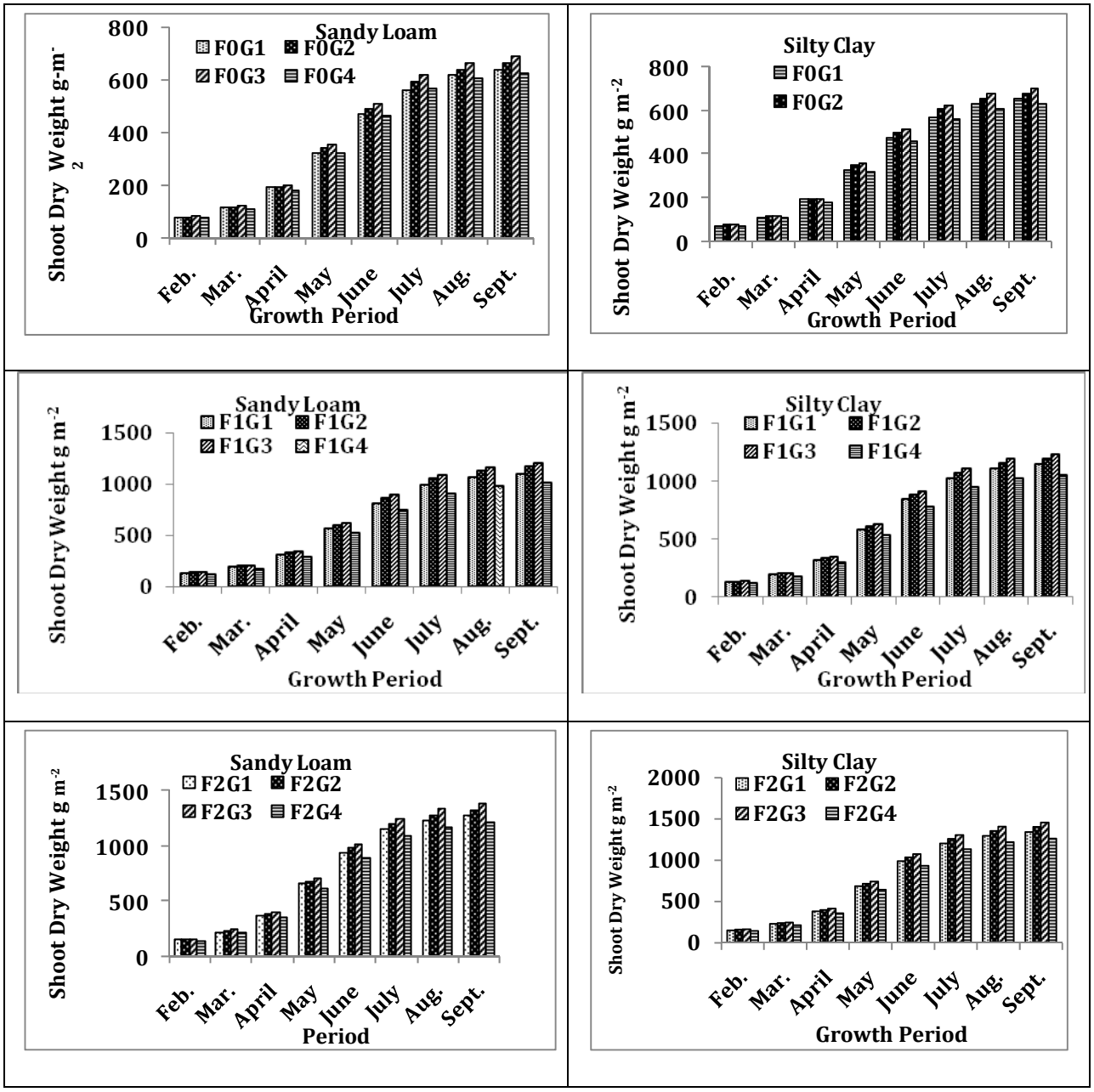
3.1 Shoot dry weight (gm^{-2})

Data regarding shoot dry weight (Table 4) indicated that interactive effects of NPK doses and planting patterns were

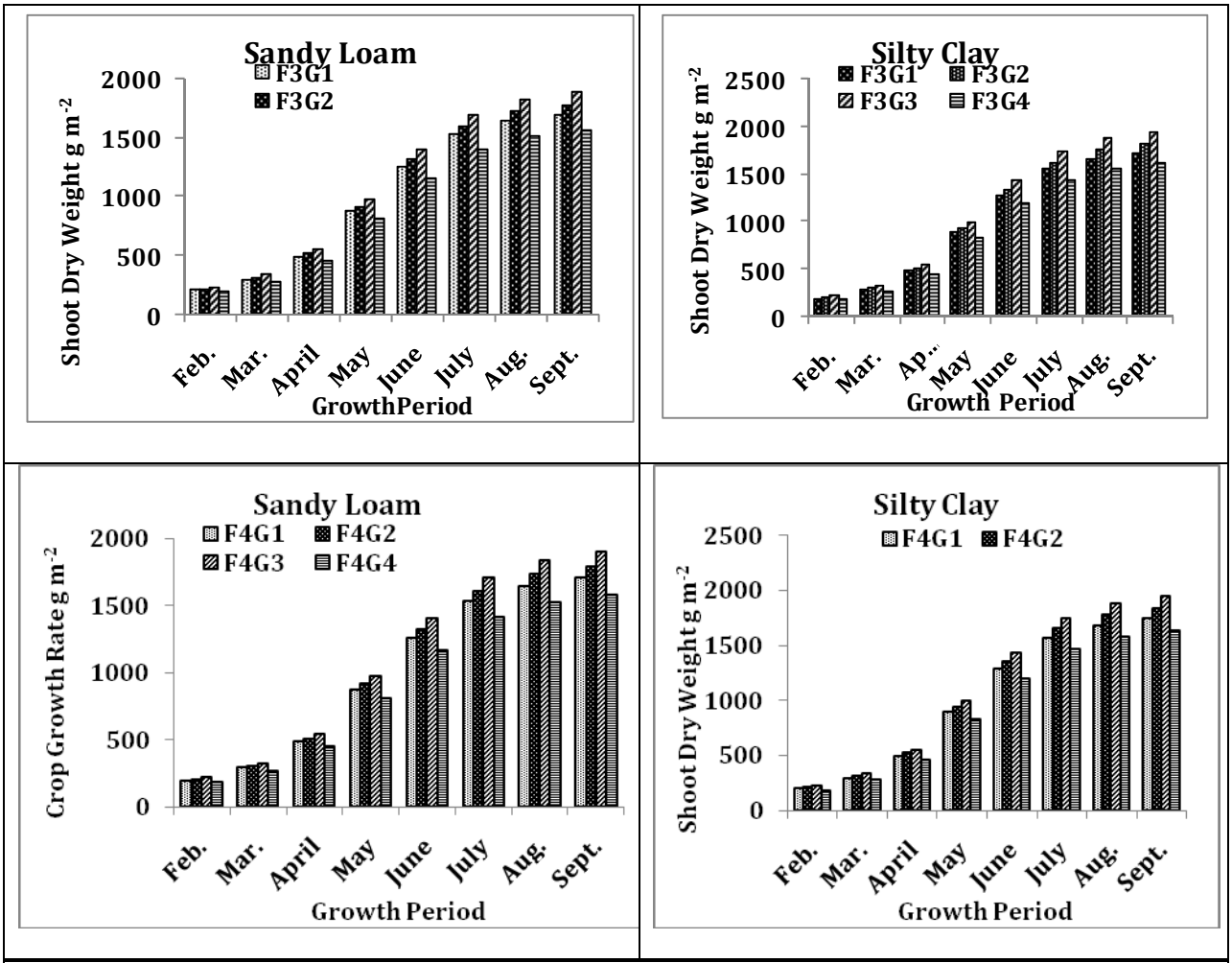
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significant at both locations. Maximum SDW was recorded 1900.8 g m^{-2}in sandy loam and 1949.2 g m^{-2} in silty clay soil in F4×G3. Minimum SDW values viz. 624.8 and 629.2g m^{-2} were observed in F0×G4 in sandy loam and silty clay soil, respectively. It was observed that shoot dry weight was increased by 204.22% and 209.8%in two soil types in F4×G3 over F0×G4. It was noted that 64, 37, 27, 1% and 64, 37, 25, 0.5% higher SDW was obtained in F4×G3 than F0×G3,F1×G_3,F2×G3 and F3×G3 in sandy loam and silty clay soil, respectively. Shoot dry weight was higher by 10,6,17 and 10, 5, 16% in F4×G3over F4×G1, F4×G2 and F4×G4 in sandy loam and silty clay soil, respectively. It was observed that SDW of F4×G3 was 66,42,33,11,10 and 66,41,31,11.3,10 % higher than F0×G1,F1×G1,F2×G1,F3×G1 and G4×G1in sandy loam and silty clay soil, respectively. The increase in SDW in F4×G3was attributed to increased nutrient availability and higher radiation use efficiency. Maximum leaf area duration was recorded in F4×G3 (Table 5), resultantly enhanced the shoot dry weight.

As far as individual factors are concerned, maximum gain was observed during the grand growth period (April-August) SDW attained constant values during the month of October each year (Fig 1).



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G_1 = 60cm G_2 = 75 cm G_3 = 30/90 cm G_4 = 30/120 cm

Shoot dry weight of autumn sugarcane as influenced by nutrient management, planting geometry and soil texture under arid conditions.

3.2 Sugar Yield

Sugar yield is the interactive effect of stripped-cane yield and sugar recovery percentage. The analysis of three years' pooled data (Table 4) depicted that different NPK doses and planting patterns affected sugar yield at both locations significantly. Maximum sugar yield 15.34 and 15.75t ha^{-1} was recorded in F3×G3 followed by F4×G3 (14.8 and 15.52 t ha^{-1}) and these were at par statistically. Minimum sugar yields 3.66 and 4.03 t ha^{-1}were recorded in F0×G1 at sandy loam and silty clay soil, respectively. It was observed that increase in nitrogen by 200 kg ha^{-1} had left no significant effect on sugar yield. Sugar yield was higher by 67.8 and 68.9% in F3×G3as compared with F0×G3in sandy loam and silty clay soil respectively. Sugar yield was also 34, 14, 16.3 and 20.9, 9.4, 18.5 % higher in F3×G3 than F3×G1, F3×G2 and F3×G4 on sandy loam and silty clay soil, respectively. Similarly it was noted that sugar yield was 76.1, 85.2, 48.3, 25.4, 28.2 and 74.4, 54, 45.3, 20.9, 19 % higher in F3×G3 than F0×G1, F1×G1, F2×G1, F3×G1 and F4×G1 on sandy loam and silty clay soil, respectively. The increase in sugar yield by 319.13% and 290.82% in F3×G3 over F0×G1 was attributed to interplay of optimum NPK availability and planting geometry which improved stripped cane yield. Increase in sugar yield in response to different fertilizer levels was also reported by Ali *et al.* (2000) and Khan et *al.* (2005).These results get supports from the findings of Sajjad *et al.* (2014) who reported that optimizing the row spacing and seeding densities improved the quality and yield of sugarcane.

3.3 Sugar Recovery Percentage

Maximum sugar recovery of 11.30 and 10.90% was recorded in sandy loam and silty clay soils in F0×G4 and minimum as 7.67 and 8.64% in F4×G1 in sandy loam and silty soil, respectively (Table 4). It was observed that 47.33 and 26.15% higher sugar was recovered in F0×G4as compared with F4×G1. It was concluded that 23.9 and 16.1 %less sugar recovery was recorded in F0×G1than F0×G4 on sandy loam and silty clay soil respectively. It was obvious that 1.2 %, 8 %, 10.2 %, 11.8 % and 0 %, 3.5 %, 7.7 % and 14.2 % less sugar recovery was displayed in F1×G4, F2×G4, F3×G4 and F4×G4 than F0×G4 on sandy loam and silty clay soil, respectively. However, low sugar recovery % viz. 18.1, 18.4, 19.6, 22.8, 28.3 and 11, 11.7, 12.6, 14.6 and 18.3 was recorded in F0×G2, F1×G2, F2×G2,F3×G2 and F4×G2 than F0×G4 on sandy loam and silty clay soil respectively. It was indicated that by increasing N and P without parallel increase of K had a negative effect on sugar recovery percentage. Similar findings were reported by Sajjad *et al.* 2014. The decrease in sugar recovery percentage with

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increase in N and P level was attributed to the facts that better availability of N resulted in increase of LA, LAI and plant height. It was obvious that the higher water up take and rapid growth, delayed maturity and less sucrose contents were resulting in lower sugar recovery percentage. The increase in recovery percentage with increase in inter strip spacing were due to improved light interception and better air circulation by way of enhanced photosynthetic activity. These results are in line with Singh and Singh (1984) and Kathirisan and Narayanasmy (1991).

Table 4: Bio economic response of autumn sugarcane to NPK doses, planting geometry and soil texture

Treatments	*Shoot dry weight (g m^{-2})*		*Sugar yield(t ha^{-1})*		*Sugar recovery (%)*		*Fertilizer use Efficiency(kgkg^{-1})*	
	Sandy loam	*Silty clay*	*Sandy loam*	*Silty clay*	*Sandy loam*	*Silty clay*	*Sandy loam*	*Silty clay*
F0 × G1	638.0r	655.6s	3.66i	4.03f	8.60l	9.15g	0.00m	0.00n
F0 × G2	657.8q	682.0r	4.14i	4.56f	9.25hi	9.70d	0.00m	0.00n
F0 × G3	686.4p	699.6q	4.94hi	4.90f	10.30cd	10.00c	0.00m	0.00n
F0 × G4	624.8s	629.2t	4.63hi	4.52f	11 .30a	10.90a	0.00m	0.00n
F1 × G1	1095.6n	1148.4o	6.41gh	7.24e	8.60l	9.1 7g	175.00j	160.82k
F1 × G2	1167.3m	1201 .2n	7.62fg	8.14de	9.22i	9.63de	187.50i	205.31g
F1 × G3	1203.4l	1236.4m	8.87efg	8.76de	10.23de	9.98c	187.50i	194.57i
F1 × G4	1012.0o	1 060.4p	7.25g	7.58e	11.1 6b	10.90a	140.00l	120.07m
F2 × G1	1276.0k	1342.0k	7.93fg	8.62cde	8.35m	8.84h	178.33j	175.85j
F2 × G2	1328.8j	1403.6j	9.17ef	9.82cd	9.08j	9.53e	186.67i	198.35h
F2 × G3	1381 .6i	1456.4i	10.26de	8.81c	9.59g	9.95c	196.67h	197.52hi
F2 × G4	1210.0l	1262.8l	9.10ef	9.31cd	10.40c	10.52b	156.67k	155.02l
F3 × G1	1683.0f	1729.2f	11 .45cd	12.46b	8.11 m	8.70i	225.00e	247.69d
F3 × G2	1771.0d	1817.2d	13.19ab	14.27ab	8.72l	9.31f	265.63b	274.57b
F3 × G3	1881 .0b	1940.4b	15.34a	15.75a	9.37h	9.56e	289.38a	290.19a
F3 × G4	1553.2h	1614.8h	12.84bc	12.83b	10.15e	10.06c	215.00g	213.94f
F4 × G1	1702.8e	1746.8e	11 .01cd	12.57b	7.67n	8.64i	21 5.56f	225.30e
F4 × G2	1790.8c	1843.6c	12.43ab	13.94ab	8.10m	8.91h	243.34d	249.19d
F4 × G3	1900.8a	1949.2a	14.81 a	15.52a	8.95k	9.35f	260.00c	261 .96c
F4 × G4	1577.4g	1632.4g	12.84b	12.1 1b	9.97f	9.35f	195.56h	195.30hi
$LSD_{0.05}$	**19.8**	**8.8**	**1.97**	**2.92**	**0.14**	**0.38**	**23.75**	**15.62**

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

3.5 Water Use Efficiency

Water use efficiency was maximum 61.3 and 97.6 kg mm^{-1} in F4×G3 (Table 5). However, it was statistically at par with F3×G3 and was minimum 15.2 and 24.4kg mm^{-}1in sandy loam and silty clay soils, respectively in F0×G4. It was observed that water use efficiency was 303.3 and 300 % higher in F4×G3 in comparison with F0×G4 in sandy loam and silty clay soils, respectively. Similarly WUE was 71 to 1% higher in F4×G3 than that of F0×G3, F1×G3, F2×G3, and F3×G3 on both soils. It was 74 to 12 % higher in F4×G3 than F4×G2, F4×G1, and F4×G4 in ediphico conditions. This appreciation in water use efficiency was due to complementary effect of better nutrient availability, efficient light interception and air circulation (Table 5). It was also observed that silty clay soil displayed 37.2 % higher water use efficiency against sandy loam soil due to better water holding capacity. Thus water saving of 344 mm was obtained in silty clay soil against the requirement of 2500 mm (Anonymous. 2014).

Fertilizer use efficiency (kg kg^{-1})

Fertilizer use efficiency was maximum 289.38 and 290.19 kg kg^{-1} in F3×G3 followed by F3×G2 (265.63 and 274.57 kg kg^{-1}), F4×G3 (260 and 262 kg kg^{-1}) and F4×G2 (243.34 and 249.19 kg kg^{-1}) in comparison with control in sandy loam and silty clay soils, respectively (Table 4). It was also observed that FUE was decreased with parallel increase in fertilizer dose from 200:200:100 to 250:200:100 NPK kg ha^{-1}. FUE was also decreased with subsequent decrease of fertilizer dose from 150:150:100 and 100:100:100 NPK kg ha^{-1}. This increase in fertilizer use efficiency was attributed to a substantial increase in stripped can yield shown in Table 5.

3.4 Benefit Cost Ratio

Benefit cost ratio (BCR) calculations revealed that effect of NPK doses and planting patterns on BCR was significantly different (Table 5). The maximum BCR was 1.64 and 1.59 in F3×G3 and minimum 0.01 and 0.02 in F0×G4 in sandy loam and silty clay soils respectively. Increase in BCR in F3×G3 was due to improved water and fertilizer use efficiency (Table 5). Increase in nitrogen level beyond 200 kg ha^{-1} had left no significant effect on BCR. It was noted that 30/120cm paired row strip planting proved better sowing method for inter cropping to harvest maximum sugar yield.

Table 5: Stripped cane yield, water and fertilizer use efficiency as affected by NPK doses, planting geometry and soil texture

Treatments	*Leaf area duration (LAD)*		*Stripped cane yield(t ha^{-1})*		*Water use efficiency (kgmm^{-1})*		*Benefit cost ratio*	
	Sandy loam	*Silty clay*	*Sandy loam*	*Silty clay*	*Sandy loam*	*Silty clay*	*Sandy Loam*	*Silty clay*
F0 × G1	466.68m	472.69m	42.50r	44.00n	15.7r	25.9n	0.05q	0.10p
F0 × G2	481.13l	482.53l	44.75q	47.00m	16.6q	27.6m	0.1 0p	0.1 6o

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F0 × G3	493.34k	489.1 4l	48.00p	49.00m	17.8p	28.8m	0.18o	0.21n
F0 × G4	469.07m	462.95n	41.00s	41 .50n	15.2s	24.4n	0.01 r	0.02q
F1 × G1	779.27i	796.44j	74.50n	79.00k	27.6n	46.5k	0.39m	0.45l
F1 × G2	809.65h	821 .48i	82.65m	84.50j	30.6m	49.7j	0.54k	0.55j
F1 × G3	825.68g	838.78h	86.75l	87.75i	32.1l	51.6i	0.61j	0.61i
F1 × G4	769.67j	781.82k	65.00o	69.50l	24.1o	40.9l	0.21 n	0.27m
F2 × G1	818.26g	837.62h	95.00k	97.50h	35.2k	57.4h	0.64i	0.65h
F2 × G2	846.87f	866.84ef	101.00j	103.00g	37.4j	60.6g	0.75h	0.74g
F2 × G3	875.97c	889.38c	107.00i	88.50i	39.6i	52.1i	0.85g	0.83f
F2 × G4	807.20h	831 .84h	87.50l	88.50i	32.4l	52.1i	0.51l	0.50k
F3 × G1	856.94e	875.11de	141.2f	143.25d	52.3f	84.3d	1 .28e	0.50k
F3 × G2	902.97b	91 8.26b	151.25d	153.25c	56.0d	90.1c	1 .45c	1 .41c
F3 × G3	947.56a	963.69a	163.75b	164.75a	60.6b	96.9a	1.64a	1.59a
F3 × G4	848.12f	862.13f	126.50h	127.50e	46.9h	75.0e	1.05f	1.01 e
F4 × G1	867.06d	876.29d	143.5e	145.50d	53.1e	85.6d	1 .27e	1 .24d
F4 × G2	91 0.76b	91 8.26b	153.50c	156.50b	56.9c	92.1b	1 .43d	1 .41c
F4 × G3	946.23a	970.93a	165.50a	166.00a	61.3a	97.6a	1 .62b	1 .56b
F4 × G4	851 .90ef	853.92g	128.75g	129.50e	15.7g	25.9e	1 .04f	0.99e
LSD 0.05	**455.34**	**602.79**	**52.67**	**9.5**	**45.6**	**70.7**	**0.02**	**0.03**

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

4. Conclusion and Recommendations

It was concluded that maximum sugar yield, fertilizer use efficiency, optimum shoot dry weight and benefit cost ratio could be obtained from nutrient dose of 200–200-100NPK kg ha^{-1}along with 30/90cm spaced paired row strip planting pattern in sandy loam and silty clay soils of arid agro climate. Sugar recovery percentage decreased by increasing the level of nitrogen and phosphorus without increasing potassium and it was improved by increasing row spacing up to 30/120cm. Therefore, nutrient dose of 200-200-100NPK kg ha^{-1}alongwith 30/90 cm paired row strip planting was recommended for maximum sugar yield.

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