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REVERTING THE GROWTH REGRESSION OF SUGARCANE INTERCROPPED WITH SUGARBEET THROUGH ENHANCED FERTILIZATION

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ABSTRACT

Intercropping is practiced mainly to fetch higher economic returns per unit area; however, it is constrained with reduction in the growth and yield of both the main crop and intercropped one as compared to their sole cultivation. This two year field study was undertaken on sugarcane-sugarbeet intercropping with the main objective to cover-up the growth as well as yield losses through improved nutrient management, ultimately for the highest economic output. Randomized complete block design with two factorial arrangements and four replications was adopted for experimental layout. Factor-1 treatments in main-plots comprised of sole cultivation of sugarcane and sugarbeet as well as intercropping of both. Sugarbeet was intercropped on 90 cm spaced ridges between rows of sugarcane being the main crop. Factor-2 in sub-plots included various levels of NPK fertilizers, viz., F_0, F_{100}, F_{150}, F_{200}, F_{250} and F_{300}, representing 0, 100, 150, 200, 250 and 300 kg ha^{-1}, respectively, each of N-P_2O_5-K_2O. Data on crop growth and yield attributes reflected statistically higher values for sole planting in control and with lower NPK doses; however, there was non-significant difference between intercropping and sole cultivation system of sugarcane and sugarbeet at higher NPK doses. Number and height of shoots, dry shoots weight, cane length and diameter, crop growth rate and un-stripped cane yield increased significantly with each increment of NPK level. The most appropriate dose of NPK was 250 kg ha^{-1} with respect to crop production and financial benefit. Sugarcane-sugarbeet intercropping proved superior to traditional sole cultivation through improved fertilization.

Key words: *Saccharum officinarum* L., *Beta vulgaris*, intercropping, integrated plant nutrient management, un-stripped cane yield, economic returns.

INTRODUCTION

Farmland size has shrunk with the rising population intensity, urbanization, road construction, and land deterioration (Rehman et al., 2014a). Nonetheless, peasants yearn for maximum return from their limited holdings, and also crave to protect themselves from the risk of crop failure (Aziz et al., 2015). Intercropping (raising short duration crop in another widely spaced crop) could be the best strategy for small farmers to intensify land use, absorb surplus rural labour, enhance radiation / nutrient use efficiency, and sustain crop production (Nazir et al., 1997; Jelic et al., 2015). Furthermore, autumn-planted sugarcane (*Saccharum officinarum* L.) occupies the land for more than a year with late returns; hence, there is no chance to grow other crops therein. The only choice during this period is to grow small-season crops in sugarcane, being quite suitable for intercropping due to its slow growth rate during winter and early spring (Nazir et al., 2002).

Sugarcane management systems greatly affect the soil characteristics, and this very fact has realized the sugar industry to refine the sugarcane production systems (Tavares et al., 2015). Further, escalating sugar crises urge to introduce intercropping system in sugarcane, which could suffice the raw material and prolong crushing season of sugar mills (Rehman et al., 2014b). Growing of two compatible sugar crops, viz., sugarcane and sugarbeet (*Beta vulgaris* L.) in the same field could fetch higher economic returns (Bahadar et al., 2007). Through increased crop

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biodiversity, intercropping improves resilience, food security and nutrition, and may provide sustainability to agricultural systems (Mousavi and Eskandari, 2011; Klimek-Kopyra et al., 2015). This is achieved through improved resource capture and utilization due to differences in spatial and temporal distribution as well as morphology of component crops (Chimonyo et al., 2015). Therefore, intercropping and rotation could be an effective tool for enhancing the crop productivity and sustain soil fertility status (Jelic et al., 2015; Feiziene et al., 2016).

Variable responses from different intercropping systems have been reported, although numerous studies affirm its economic benefits compared to mono-cropping by increased yield through effective use of space with interspecific competition for resources and mutual crop interactions (Dunea and Dincă, 2014). Several factors, viz., plant density, sowing time, compatible crops, nutrient management as well as farmers' and the region's socio-economic conditions influence the profitability of intercropping (Aziz et al., 2015). Intercropping could be more productive than mono-cropping but it falls into competition for resources (Humphries et al., 2004; Harris et al., 2008). Competition for nutrients among plants may reduce the yield of mono-crops included in intercropping as evidenced through lower values of specific root length (SRL) for plants in mixture (Klimek-Kopyra et al., 2015). Under sugarcane-sugarbeet system, sugar content in cane juice, cane weight and yield were significantly reduced, although intercropping rendered greater economic returns compared to sole sugarcane crop (Soomro, 2008). Sugarbeet also has phytotoxic potential of allelopathic effect for reducing weed intensity and growth in the field, so it is beneficial to include in the cropping system (Dadkhah, 2013).

Productivity of sugarcane mainly depends on the use of chemical fertilizers, which results in nutritional balance. Status of plant nutrients in soil, and practices for their management in the field greatly influence the crop response in terms of production and economics under a specific agro-ecology (Ullah et al., 2013). This study evaluated the compatibility and growth performance of sugarcane through intercropping and monocropping systems with integrated use of NPK fertilizers under arid conditions.

MATERIAL AND METHODS

Study site

This field study was conducted to compare the growth of intercropped sugarcane-sugarbeet with that of their sole cultivation under various rates NPK fertilizer application. Field experiments were carried out at the Research Farm of Agriculture Research Institute, Rata Kulachi, Dera Ismail Khan, Pakistan during 2009-10 and 2010-11. Experimental area falls under the agro-ecological zone of Sulaiman Piedmont plains having subtropical continental arid climate characterized by hot summer, mild winter and low humidity. Mean daily maximum (summer) temperature is 40-43ºC and minimum (winter) temperature is 5.8-7.6ºC, and mean annual rainfall is 327 mm. Basic analysis of composite soil samples drawn from the experimental site used during first year (2009-2010) indicated that soil texture was clay loam with its pH 8.0, EC 4.6 dS m^{-1}, bulk density 1.3 g cm^{-3}, content of total N 0.05%, available P 8.0 mg kg^{-1} and extractable K 80 mg kg^{-1}. Soil analysis results for the site of second year experiment revealed that soil had clay loam texture, pH 8.1, EC 5.2 dS m^{-1}, bulk density 1.35 g cm^{-3}, content of total N 0.06%, available P 8.5 mg kg^{-1} and extractable K 92.5 mg kg^{-1}.

Experimental

Both year field experiments were conducted through randomized complete block design (RCBD) having two factor factorial arrangement and four replications. Factor-1 treatments in the main-plots (30 m × 5 m) comprised of sole cultivation of sugarcane and sugarbeet as well as intercropping of both. Sugarcane variety "HSF-240" and sugarbeet variety "Antak" were grown. Factor-2 in sub-plots (4.5 m × 5 m) included six graded fertilizer doses as: F_0, F_{100}, F_{150}, F_{200}, F_{250} and F_{300}, representing 0, 100, 150, 200, 250 and

300 kg ha^{-1}, respectively, each of N-P_2O_5-K_2O. Types of fertilizers used to supply these amounts of N-P_2O_5-K_2O for N-P-K, respectively, were: urea for major share of N, diammonium phosphate (DAP) for whole P considered as P_2O_5 and also contributing some amount of total N applied, and sulphate of potash (SOP) supplied all of K as K_2O. Sugarcane stem-cuttings (sets) were placed in 90 cm spaced rows / ridges on dry field and irrigated soon after planting. After attaining field capacity moisture condition of the soil (20 days after planting the sugarcane), sugarbeet seeds were dibbled manually on the ridges by maintaining plant to plant distance of 15 cm. Whole of the phosphate and potassium fertilizers were applied before planting of sugarcane and thoroughly mixed to distribute them uniformly in the field, whereas, nitrogen was applied in three equal split doses; the first after complete germination (at the end of February), the second at the start of cane formation stage (at the end of March) and the third after uprooting the sugarbeet (during May). Other agronomic practices required to both crops were implemented uniformly in all the treatments. Pre-emergence herbicide (Dual Gold) was applied in the field to control weeds. Earthing-up around sugarcane plants was carried out in the first week of June. Number of irrigations to both sole / intercropped sugarcane was 19 during first year and 17 in the second year, each of 10 cm depth above the field surface. Total rainfall during the respective years was 328 mm (2009-10) and 584 mm (2010-11).

Crop data

Data regarding the growth and yield attributes of autumn sugarcane crop were recorded by following the standard procedures as described here. Before earthing-up at 90 days after sowing, intensity of sugarcane shoots in 1 m^2 area was counted from each treatment plot. For shoots dry weight (g m^{-2}) of autumn sugarcane, five randomly selected cane shoots from each treatment at 30 days interval were cut, sun-dried and then oven-dried at 70ºC for 72 hours to a constant dry weight. Dry weight per shoot was converted to dry weight m^{-2} by multiplying it with total shoot count m^{-2}. Plant height or shoot length (m) of ten randomly selected un-stripped canes from each treatment was measured with measuring tape from bottom to apex at the time of harvest, and then it was averaged. Cane length (m) of ten randomly selected stripped canes from each treatment plot was measured from base to the tip of last internode, and then averaged. Cane diameter (cm) of the same randomly selected ten canes was measured with Vernier caliper from the base, middle and top internodes and averaged. For un-stripped cane yield, all the un-stripped canes at harvest from three central rows (W 2.7 m × L 3.7 m = 10 m^2) of each treatment sub-plot were harvested and weighed. Data were transformed mathematically to yield per hectare. Benefit-cost ratio (BCR) was calculated as below (CIMMYT, 1988):

$$\mathrm{BCR} = \frac{\text{Gross income (Rs)}}{\text{Total cost (Rs)}}$$

Crop growth rate (CGR) was worked out by the equation proposed by Hunt (1978):

$$\mathrm{CGR}\,(\mathrm{g\,m^{-2}d^{-1}}) = \frac{(W_2 - W_1)}{(T_2 - T_1)}$$

where, W_1 and W_2 are the total dry weights harvested at times T_1 and T_2, respectively.

Statistical analysis

Effect of experimental variables (intercropping × NPK fertilizer levels) was studied on sugarcane growth and yield parameters. For both crops, data were subjected to two-way analysis of variance (ANOVA) and Statistix 8.1 software was used (Steel and Torrie, 1997). Treatment means of each variable were compared through least significant difference at 5% probability level.

RESULTS AND DISCUSSION

Intensity of shoots

Number of shoots per unit area is an important parameter for maintaining the optimum sugarcane crop yield. Analysis of two years pooled data on sugarcane shoots intensity/count revealed that it was significantly affected by elevating the NPK doses both under sole sugarcane cultivation or intercropping with sugarbeet (Figure 1). Shoots intensity increased gradually from F_0 to F_{300} in response to enhanced NPK fertilizer doses, similarly in both sole and intercropped sugarcane. Higher fertilizer doses (F_{250} and F_{300}), both being statistically similar, showed significantly greater shoot intensity as compared to lower fertilizer treatment levels. This could be due to the reason that original soil fertility was not sufficient to meet the nutritional requirement of both crops during their growth, thus fertilization significantly increased the number of sugarcane shoots. Nitrogen and potassium stress to sugarcane significantly reduces uptake of nutrients and amino acid content, so lower levels of both N and K reduce the growth and proliferation of plant shoots (Subasinghe et al., 2007). Sugarcane planted alone recorded higher shoots intensity than under intercropping with other crops. It was further noted that 67.3, 63.0,40.5, 21.7 and 14.1 %, and 71.9, 61.8, 37.0, 19.2 and 9.2% higher number of shoots were recorded in sole and intercropped sugarcane, respectively under F_{300}, F_{250}, F_{200}, F_{150} and F_{100} over control (F_0). Increased number of sugarcane shoots through enhanced NPK doses was also obtained by Khan et al. (2005).

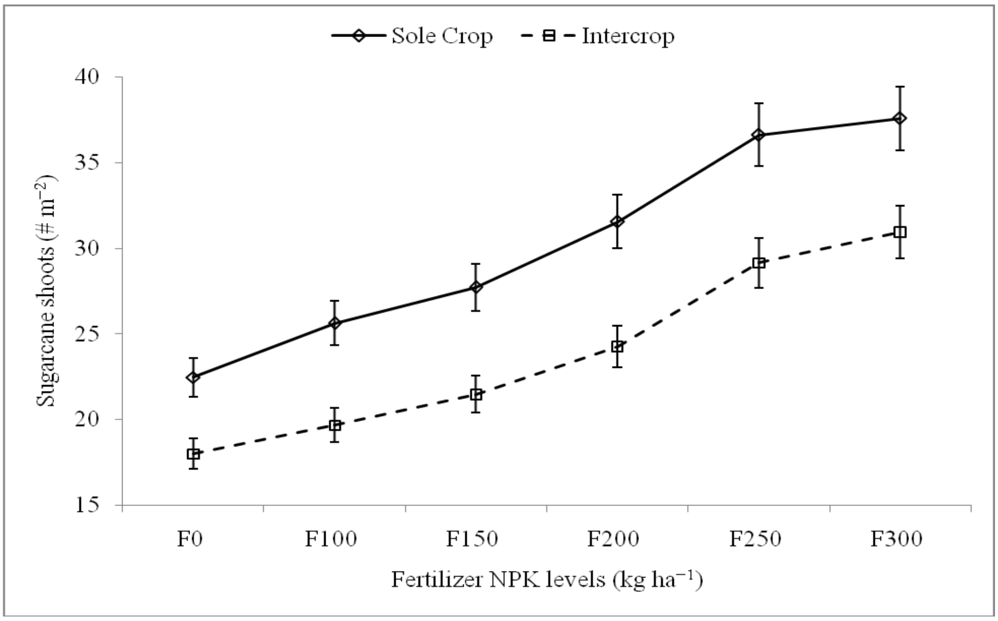

Figure 1. Sugarcane shoots count under sole- and inter-crop planting system with various NPK levels. Vertical bars represent ±SE of means (n= 4)

Dry shoots weight

Data on the weight of sugarcane dry shoots depicted statistically significant impact of the NPK doses, and intercropping also exhibited significant difference with sole crop (Figure 2). Weight of dry shoots under sole cropping increased sharply from F_0 to F_{250} in response to enhanced NPK fertilizer doses, and impact of further higher dose (F_{300}) was non-significant as compared with F_{250}. Similar response under intercropping was observed that F_{250} and F_{300} rendered the highest values statistically different from lower NPK treatments which differed significantly with each other. Sole sugarcane cultivation showed significantly higher values than under intercropping at all fertilizer levels. Significant increase in response to higher dose of NPK was due to more nutrients availability to plants for tillers formation in the treatments receiving higher doses of NPK (Bakhtiar et al., 2002; Sarwar et al., 2009). It was also found that there was 165, 158, 128, 104 and 73%, and 191, 184, 159, 127 and 84% higher dry shoots weight under sole and intercropped sugarcane, respectively with F_{300}, F_{250}, F_{200}, F_{150} and F_{100} over control treatment (F_0). Increase in N and K fertilizer doses to sugarbeet resulted in the highest total dry matter production and its partitioning into other plant tissues (Kashem et al., 2015).

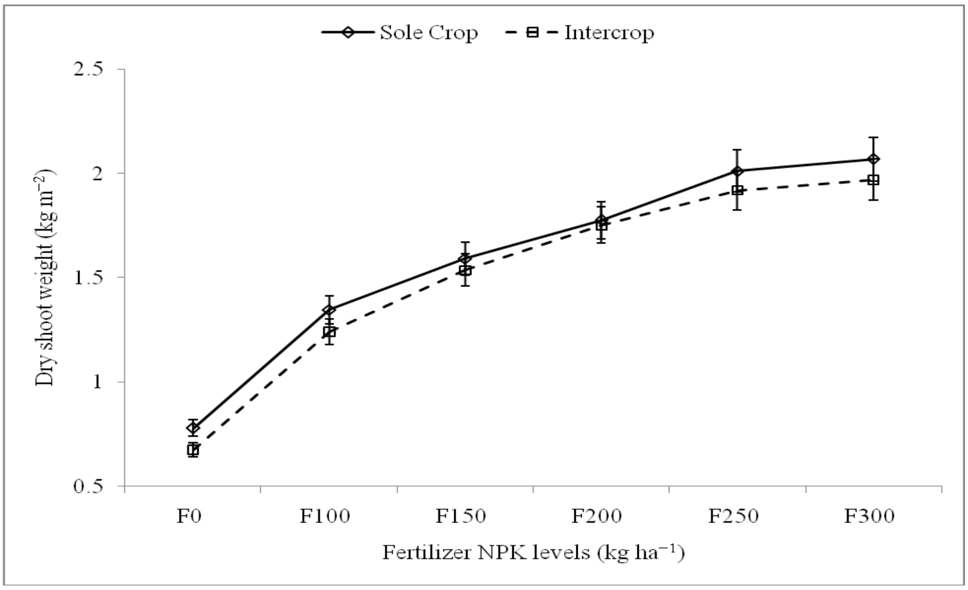

Figure 2. Sugarcane dry shoots weight under sole- and inter-crop planting system with various NPK levels. Vertical bars represent ±SE of means (n= 4)

Shoot height

Sugarcane exhibited greater shoot height with enhanced NPK doses being statistically superior with F_{250} and F_{300} over other NPK levels (Figure 3). Intercropping depicted statistical difference with sole sugarcane crop, and their interaction was also found significant. Sole crop gave greater shoot length than that of intercropped sugarcane plants. Shoot length is an important yield attribute that directly affects the final sugarcane yield. Significant gain in shoot height of cane in response to higher doses of fertilizer could be due to the role of NPK in the synthesis of plant biomass (Nadeem et al., 2011; Aslam et al., 2014). There was 62.7, 59.4, 44.9, 28.8 and 19.8%, and 64.7, 62.1, 46.8, 30.5 and 21.6% greater sugarcane plant height as obtained from the sole and intercropping, respectively in F_{300}, F_{250}, F_{200}, F_{150} and F_{100} over F_0. Whereas, intercropping of sugarcane with other crops, e.g., sugarbeet, variably lowers the amount of nutrients available to sugarcane, which ultimately reduces its growth and production (Soomro, 2008).

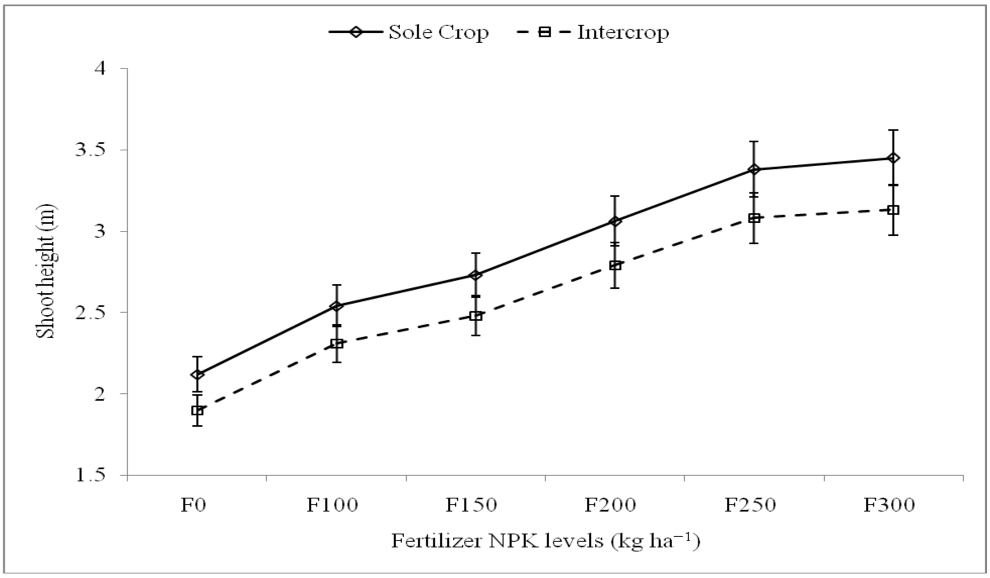

Figure 3. Sugarcane shoots height under sole- and inter-crop planting system with various NPK levels. Vertical bars represent ±SE of means (n= 4)

Cane length

Cane length is the net outcome of genetic potential of a variety and management practices. Statistical analysis of two years pooled data of cane length revealed that it was significantly affected by NPK doses (Figure 4). Intercropping exhibited significant difference with monocropping, and their interaction was also found significant. Sole crop resulted in significantly greater cane length than from intercropped plants. The longest canes were obtained through F_{300} and F_{250} treatments with non-significant difference with each other under both sole and intercrop cultivation. On the overall, NPK fertilizer levels improved cane length over control (F_0) significantly with each increment. It was also noted that 38.69, 35.68, 31.16, 19.60, 12.06% and 30.51, 30.51, 27.68, 23.73 and 9.60% higher cane length was obtained in sole and intercrop, respectively from F_{300}, F_{250}, F_{200}, F_{150} and F_{100} over F_0 (control) treatment. Khan et al. (2005) also reported an increase in cane length with increasing fertilizer doses.

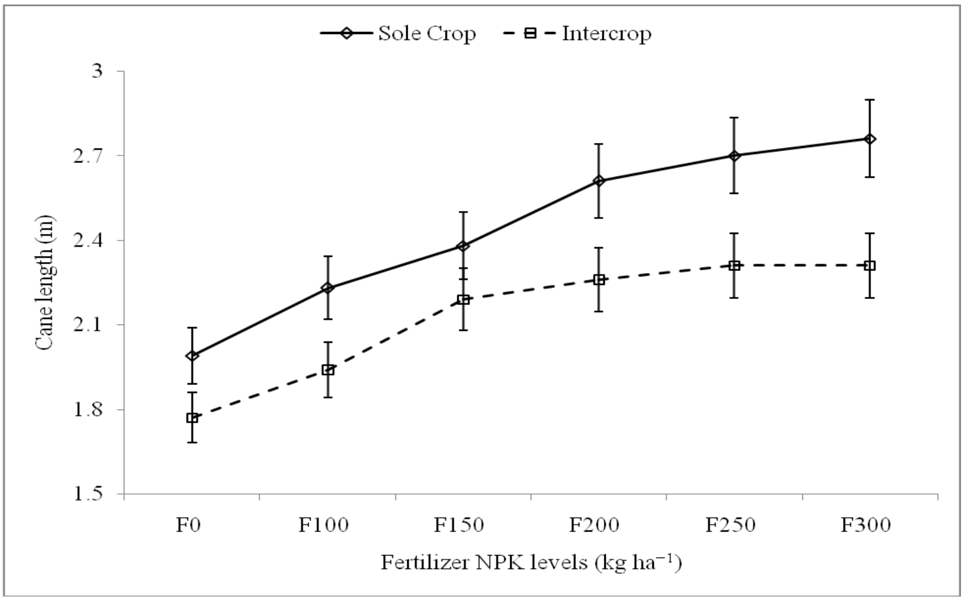

Figure 4. Cane length under sole and inter-crop planting system with various NPK levels. Vertical bars represent ±SE of means (n= 4)

Cane diameter

Data of cane diameter indicated that it was significantly affected by NPK doses as well as intercropping, and interaction of both also rendered significant differences among various treatment combinations (Figure 5). Cane diameter exhibited greater values from sole sugarcane crop than that of sugarcane plants intercropped with sugarbeet. The highest cane diameter was recorded with F300 followed non-significantly by F_{250} dose for sole sugarcane, and F_{300}, F_{250} and F_{200} levels of NPK in intercropped sugarcane crop differed non-significantly. Lower levels of NPK (F_{150} and F_{100}) were statistically at par with each other as well as with control. Increasing trend in cane diameter was observed with increase in fertilizer doses. As increase in nutrient doses enhanced the nutrient availability to plants, so due to complimentary effect of N, P and K, all the energy was utilized for increasing the plant biomass. It was observed that there was successive increase in cane diameter with higher NPK levels. These results are in agreement with that of Nadeem et al. (2011) and Islam et al. (2013) showing an increase in sugar recovery with enhanced fertilizer doses. It was also noted that 48.29, 40.98, 32.68, 16.59, 8.29% and 40.32, 26.34, 20.43, 8.60 and 4.84% higher cane diameter was obtained in sole and intercropped, respectively through F_{300}, F_{250}, F_{200}, F_{150} and F_{100} treatments when compared to F0 (control). Sugarcane alone rendered greater cane diameter compared to that from its intercropping with onion, canola, sunflower (Soomro, 2008) and sugarbeet (Rehman et al., 2014a).

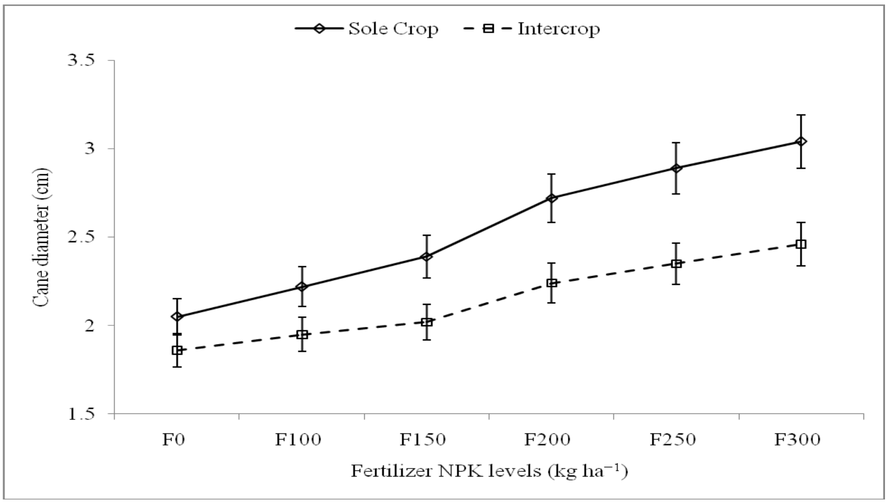

Figure 5. Cane diameter under sole and inter-crop planting system with various NPK levels. Vertical bars represent ±SE of means (n= 4)

Un-stripped cane yield

Un-stripped cane yield is the result of interactive effects of crop growth and yield attributes and. Statistical analysis of two years pooled data advocates that un-stripped cane yield increased significantly by elevated levels of NPK, and intercropping also has significant difference with sole crop (Figure 6). Sole crop showed higher cane yield than from intercropped sugarcane up to 200 kg ha^{-1} of NPK fertilizer rate. The highest cane yield (239.3 t ha^{-1}) was obtained with F_{300} in sole sugarcane crop, being statistically at par with that under F_{250} in sole crop (237.0 t ha^{-1}) and that with F_{300} under intercrop sugarcane (232.9 t ha^{-1}). Treatments with higher doses of NPK attributed to better cane length and its density which ultimately rendered higher un-stripped cane yield. These results emphasize that enhanced fertilizer dose could compensate the yield reduction resulting from intercropping. Jelic et al. (2015) advocated that crop productivity could be improved by sustaining soil fertility status through integrated plant nutrient management. Soomro (2008) found that cane yield was reduced under sugarcane-sugarbeet intercropping. Rehman et al. (2014b) indicated that un-stripped cane yield was significantly higher in sole compared to intercropped sugarcane. Improvements in un-stripped cane yield with increased fertilizer doses (F_{300}, F_{250}, F_{200}, F_{150} and F_{100}) over control were as: 131, 129, 115, 58 and 37% in sole sugarcane, and 243, 138, 119, 57 and 38% for intercropped sugarcane, respectively. Khan et al. (2005) also reported an increase in un-stripped cane yield with increasing fertilizer doses.

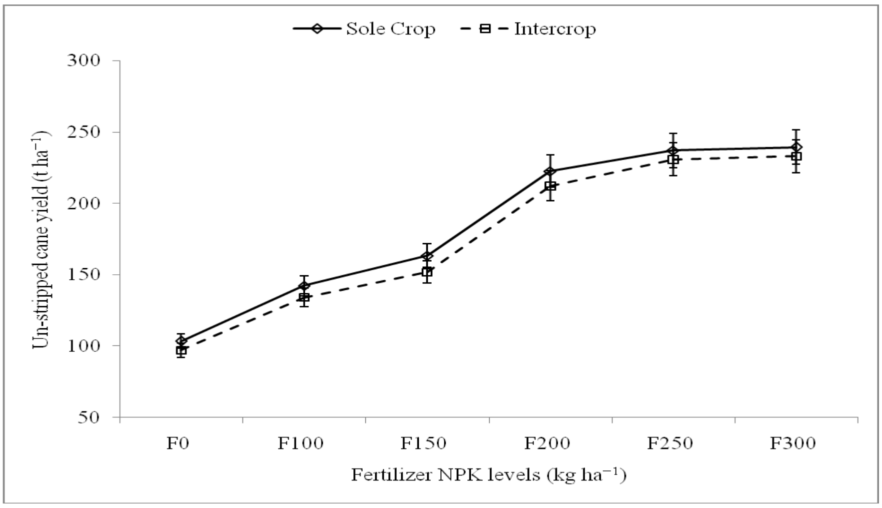

Figure 6. Un-stripped cane yield under sole and inter-crop planting system with various NPK levels. Vertical bars represent ±SE of means (n= 4)

Crop growth rate

Crop growth rate (CGR) refers to the rate of dry matter accumulation per unit area per day. The CGR of sole sugarcane crop and that of intercropped with sugarbeet at respective NPK rates were statistically similar (Figure 7). There was significant increase of CGR with each increment of NPK dose up to F_{200} beyond which there was no statistical difference as for F_{200} and F_{200}. This could have been due to the reason that sufficient nutrients have been available to the crop from F_{200} dose during the vegetative growth period. Therefore, CGR values for F_{200}, F_{250} and F_{300} under sole sugarcane crop were statistically similar to each other but higher than that of lower fertilizer rates and control. Interactive effects of NPK levels and sugarcane-sugarbeet intercropping on BCR were also significant. Rehman et al. (2014a) reported higher CGR value of sole sugarcane than that for intercropped. Slightly higher CGR in sole sugarcane was due to no crop competition, nutrients and space availability, and greater specific root length enhancing the water uptake (Klimek-Kopyra et al., 2015).

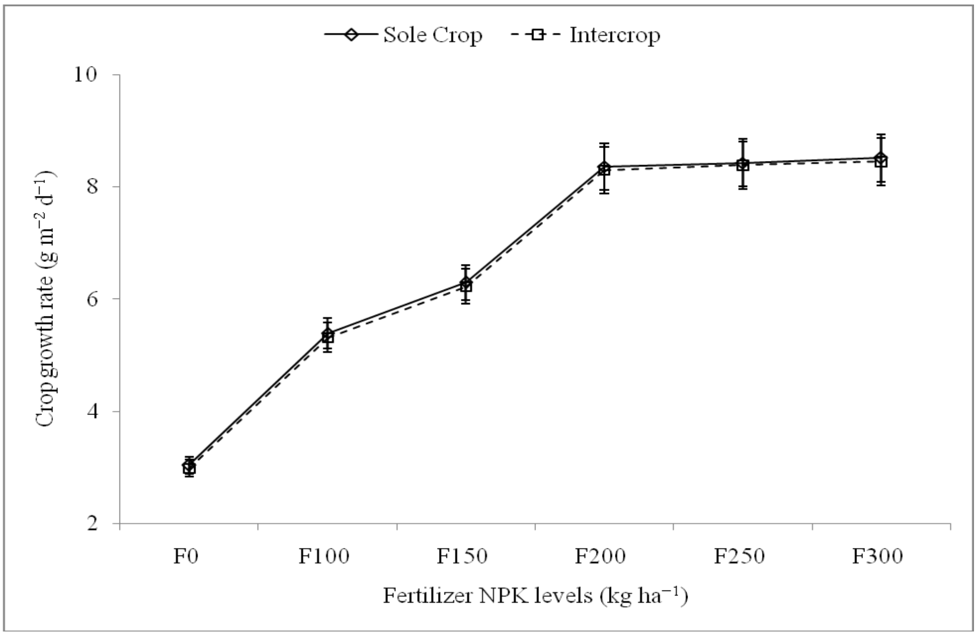

Figure 7. Crop growth rate of sugarcane under sole and inter-crop planting system with various NPK levels. Vertical bars represent ±SE of means (n= 4)

Benefit cost ratio

Benefit cost ratio (BCR) being an indicator of net economic return, ranged from 1.57 to 5.09 in response to elevated NPK rates, and intercropping showed greater BCR than that with sole crop (Figure 8). The highest BCR (5.09) was obtained with F_{250} in intercropped sugarcane, followed by F_{300} rendering slightly lower BCR (4.97) but statistically similar to that under F_{250}. The BCR values for F_{200}, F_{250} and F_{300} for sole sugarcane were statistically similar to each other but higher than that of lower NPK fertilizer rates and control. Interactive effects of NPK levels and intercropping on BCR values were also significant reflecting an increase in response to enhanced doses of NPK. Greater BCR values are due to efficient use of resources, including nutrients, air circulation and light, which collectively improved the cane yield and net returns (Rehman et al., 2014b). Sugarcane-sugarbeet intercropping rendered greater BCR than that from sole sugarcane crop (Soomro, 2008). Increased P-fertilizer application rates have been found to enhance the value-to-cost ratio successively (Rasheed et al., 2010).

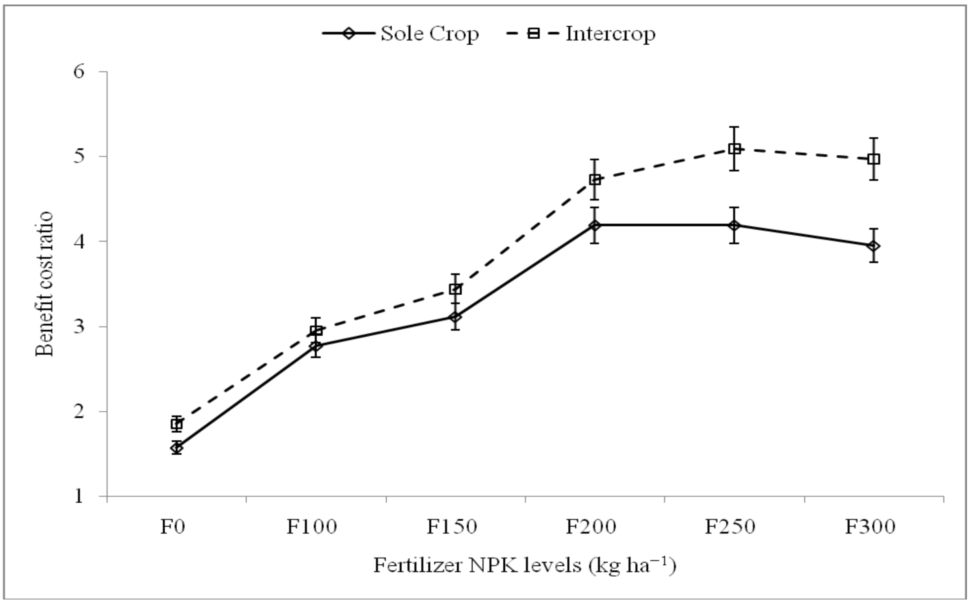

Figure 8. Benefit cost ratio of sugarcane cultivation under sole and inter-crop planting system with various NPK levels. Vertical bars represent ±SE of means (n= 4)

CONCLUSIONS

In this study, feasibility of sugarcane-sugarbeet intercropping against their sole cultivation was worked out through enhanced NPK (in equal amounts) levels (0, 100, 150, 200, 250 and 300 kg ha^{-1}) during two years field experimentation. Values of crop growth and yield attributes were slightly reduced due to intercropping as compared to respective sole crops of sugarcane and sugarbeet, and the difference was non-significant at higher NPK doses. However, cumulative yield and economic benefit from both the crops under intercropping was greater than that with sole cropping. The second highest dose of NPK (F_{250}) equalled statistically with the highest level of fertilizer NPK (F_{300}) for most of the parameters in both intercropped and sole crops. Benefit cost ratio was also higher with F_{250}. Therefore, it is concluded, mainly in economic terms, that sugarcane-sugarbeet intercropping pays back greater than growing the sugarcane separately, and the most appropriate NPK application rate is 250 kg ha^{-1}. These findings further indicate that sugarcane growth and yield reductions due to sugarbeet intercropping at lower fertilizer levels could be compensated by enhanced fertilization even with better financial returns as compared to sole cropping.

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