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Differential Responses in Crop and Sugar Production of Intercropped Sugarcane and Sugar Beet to the Application of Some Organic Amendments

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Abstract. Soil productivity and fertility tends to decline if the nutrient requirement of an intensive cropping system is not managed prudently. Long term use of sole chemical fertilizers exhausts the indigenous pools of carbon and non-applied nutrients. It was a two factorial quadruplicated in randomized complete block design (RCBD) field experiment. Factor-1 treatments were cultivation of sole sugarcane and sugar beet, along with intercropping of both. Factor-2 included organic amendments, *viz.,* farmyard manure (FM), press mud (PM) and compost (CP) used at (10 t/ha) with fertilizer rates (100, 250 Kg/ha) each of N-P_2O_5-K_2O. Crop yield attributes and sugar yield data gave non-significantly difference between intercrops and cultivation of sugarcane and sugar beet sole, although there were slightly higher values for planting sole. Higher dose of NPK *viz*., 250 Kg/ha combined with FM gave better response regarding crop and sugar production and maximum economic returns. Sugarcane sugar beet intercropping proved financially higher to outdatedfarming system through integrated plant nutrient management. Among organic amendments, CP performed lower, while FM rendered upper values of crop and sugar production at both rates of fertilizer.

Keywords: sugar beet, integrated nutrient management, stripped cane, recovery, BCR

Introduction

Soil productivity and fertility tends to decline if the nutrient requirement of an intensive cropping system is not managed prudently. Use of chemical fertilizers on long term exhausts the indigenous pools of carbon and non-applied nutrients. Moreover, use of expensive mineral fertilizers provokes financial crisis particularly to the small farmers (Akter *et al*., 2004). Hence, they are switching over to phased out farming practice of using compost and manures just for optimum returns (Rehman *et al*., 2014). Also, organically produced commodities satisfy the consumer's choice by having better nutritive value and environmental safety than the conventional crops (Khaliq *et al*., 2021). Residual effect of organic manures may beevident more, as some portion of nutrients is accessible to the first crop and left over portion of nutrients will be obtainable to the following crop (Tahir *et al*., 2011). Similarly use of manures and mineral fertilizers in combinations augments the crop yield plus quality besidesnourishing the soil health and system's productivity (Waseem *et al*., 2012).

Due to reduced land holdings, farmers need higher returns from a small area with their scarce resources (Khaliq *et al*., 2020) and also want to secure themselves from low yield / income or crop failure situations. Intercropping is acknowledged to increase the cane yield, exploit net returns and better resource utilization (Degefa *et al*., 2016). Through crop biodiversity is improved and consumption of nutrients and water is effective more food security and nutrition (Chandrakar *et al*., 2019). Thus risk of crop failure is curtailed. Generally, sugarcane and sugar beet are grown in the same field and are well-suited with each other.

In spite of strong claims for economic benefits compared to mono-cropping, variable response from different intercropping systems has been obtained (Ullah, 2016). Intercropping could be more productive and economical than mono-cropping but it falls into competition for resources e.g. nutrients which reduce the yield of both crops (Wang *et al*., 2020).

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The availability of plant nutrients and practices for their agronomic management in the field significantly impact the crop response in terms of production and economics under a given agro-ecological condition (Ofori *et al*., 1987). Cane yield and net return were greater in cane-potato intercropped system than single mono crop due to the residual effect of applied fertilizer to intercrop (Imam *et al*., 1990). It was found that intercropping of pulses provides alternative food source and income while improving the totalefficiency of land without destroying sugarcane crop yield. Intercrops produced higher net return and land equivalent ratio over the sugarcane alone. It is possible to produce higher productivity per unit area in intercropping if the nutrients requirement of crops is managed properly (Akter *et al*., 2004).

Hence, the present study was commenced to match the economic feasibility of sugarcane sugar beet intercropping versus these sole crops through integrated nutrient management system and sugarcane sugar beet intercropping model may be introduced to make available raw material and extend crushing season of sugar mills in Pakistan.

Materials and Methods

Site and soil properties. This field experiment compared the application of NPK fertilizers alone against their integrated use with different organic manures on sole, as well as intercropped sugarcane sugar beet cultivation on the research area of Agriculture Research Institute, Rata Kulachi, Dera Ismail Khan, Pakistan for two years, *viz*., 2009-10 and 2010-11. Site falls in country's 10^{th} agro-ecological zones having subtropical continental arid climate characterized by hot summer, mild winter and low humidity. Mean daily maximum (summer) temperature is 40-43 °C and minimum (winter) temperature is 5.8-7.6 °C and average annual rainfall is 327 mm. Original soil characteristics before first year (2009-2010) crop cultivation were as: clay loam textured soil having bulk density, 1.35 g/cm; pH, 8.5; contents of total N, 0.6 g/Kg; EC, 4.5 dS/m extractable K, 85 mg/Kg and available P, 8.5 mg/Kg, while, second year's soil analysis of experimental site indicated almost similar characteristics as: clay loam soil texture, bulk density, 1.35 g/cm; pH, 8.2; available P, 8.60 mg/Kg , contents of total N, 0.67 g/Kg; EC, 5.2 dS/m and extractable K, 92.58 mg/Kg. It reveals that soil was alkaline slightly with low fertility characteristics.

Treatments and methodologies. Two factors factorial field experiment having four replications with randomized complete block design (RCBD). Factor-1 treatments designated to the main plots (30 m × 5 m) were for cultivation pattern of two sugar crops as: sole sugarcane, sole sugar beet and intercropped sugarcane sugar beet. Sugarcane variety HSF-240 and variety of sugar beet Antak were grown. Factor-2 treatments placed in the sub-plots (4.5 m × 5 m) included application of fertilizer and organic manures as: farm yard manure (FM), press mud (PM) and compost (CP) applied at the rate of 10 t/ha in blend with two fertilizer (F) rates (100 and 250 Kg/ha) as N-P_2O_5-K_2O, along with a check treatment without any organic amendment or fertilizer. Fertilizer of Nitrogen, Phosphorus and Potash were applied at the rates of 170-110-110 NPK Kg/ha respectively in the form of Urea, DAP and SOP.

Sugarcane sets were placed in 120 cm spaced dual rows ridges in well prepared soil and light irrigation were applied soon after sowing. When workable soil moisture condition were attained 20 days after sowing, sugar beet seeds were sown by dibbling manually on the ridges. The plant to plant distance of 15 cm were maintained for sugar beet plants. Whole of the P and K fertilizers were applied before planting of sugarcane and thoroughly mixed to distribute them uniformly in the field.

The nitrogen fertilizer was equally applied in three splits. First N dose were applied after complete germination i.e. at end of February, second at the end of March i.e. start of cane formation stage and third dose of Nitrogen were applied during the month of May i.e. after uprooting the sugar beet.

Other agronomic practices required to both crops were performed similarly in all the treatments. The granular insecticide Furodon was applied i.e. 16 Kg at sowing, 8 Kg at earthing up. Pre-emergence herbicide Acetachlor was applied @ 1.5 liter per acre with 1^{st} irrigation and it will control all types of weeds for first 30 days. After 50 days of planting, post emergence herbicide Gang-V @ 1.5 liter per acre was sprayed in proper soil moisture condition / wattar. These two herbicide application will control all types of narrow and broad leaf weeds effectively. Earthing-up was undertaken around cane stems in the first week of June at 90-110 days after planting. If earthing up was delayed after 2^{nd} week of June, breakage of cane stem will be occurred. Number of total irrigations applied was 18 during the first year

and 16 in the second year cropping season, each of 10 cm depth above the field surface.

Crop parameters and procedures. Effect of experiment variables was studied by recording the parameters correlated to growth and yield of sugarcane and sugar beet crops, sugar recovery, economic return and land use efficiency through procedures as described below: Germination was completed 45 days after sowing. Germination and seedlings in each sub-plot was calculated and subsequently germination percentage was planned as:

$$\text{Germination (\%)} = \frac{\text{Number of germinated seed}}{\text{Total number of seeds sown}} \times 100$$

For crop yield all the stripped canes / beet roots from three rows of each sub-plot were harvested and then weighed (Kg) and the data were convertedto tonnes per hectare.

LER. Land equivalent ratio is the relative land area under sole crops that is required to produce the yields achieved in intercropping and was work out according to the procedures as proposed by Crookston and Hill (1979). The crop yield per hectare was calculated as:

$$\text{Crop Yield (t/ha)} = \frac{\text{Crop weight in sample area (Kg)}}{\text{Size of sample area (10 m}^2\text{)}} \times \text{Area of one hectare (10}^4\text{ m}^2\text{)}$$

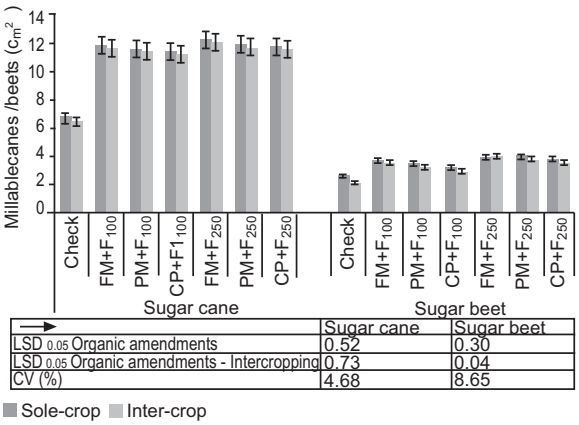
The sugar yield were work out as given below:

Sugar yield= Sugar content (%) × Stripped cane or beet root yield (t/ha)100

Statistical analysis. Data were analyzed statistically by analysis of variance (ANOVA) and treatments were compared through least significant difference (LSD) at 5% probability(Steel *et al*., 1997) by applying Statistix 8.1 software.

Results and Discussion

Millable canes and beets. Two years' combined data on the count of canes millable and sugar beets depicted statistically significant impact of NPK doses and application of various organic amendments on cane / beet root formation (Fig. 1). However, intercropping exhibited non-significant difference with sole cropping of both species. Comparatively, there was significantly higher count of millable canes as compared to the sugar beets under all the treatments. It increased gradually

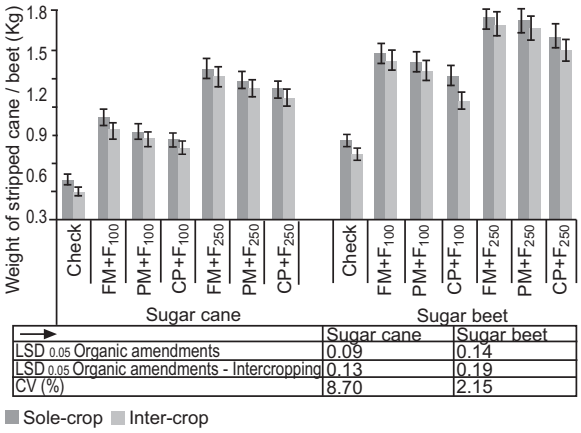


→	Sugar cane	Sugar beet
LSD 0.05 Organic amendments	0.52	0.30
LSD 0.05 Organic amendments - Intercropping	0.73	0.04
CV (%)	4.68	8.65

Fig. 1. Millable number of sugarcane and sugar beet under sole and inter-cropping plantation with synergistic use of nitrogen fertilizer and organic amendments.

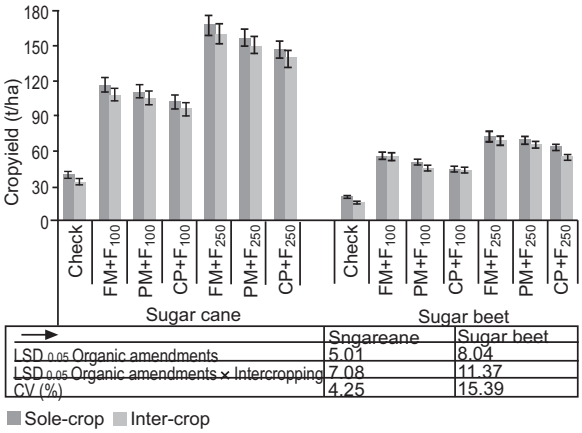
from F_0 (check) to F_{250} in response to enhanced NPK fertilizer doses, similarly in both sole and intercropped sugarcane and sugar beet. Number of millable canes and sugar beets under F_{250} dose with all manure treatments was higher than those receiving F_{100} rate. Among the organic amendments, FM rendered the highest count, while CP performed the lowest at both fertilizer doses. It could be due to the reason that composting produces slow release fertilizer and nutrient availability (especially P) from compost is governed by complex abiotic and biotic mechanisms (Sami *et al*., 2018). Crop cultivation sole indicatedmarginally higher values than intercropping at all applied fertilizer intensities/ level and with all organic manures; however, the difference was statistically non-significant. It has also been indicated by Wang *et al*. (2020) that number of millable canes was higher in sole compared to intercropped sugarcane. Major increase in response to greater dose of NPK was owing to additional nutrients ease of use to plants during tillers formation in the treatments getting greater doses of fertilizer.

Weight of cane and sugar beet. Stripped cane and beet root weight exhibited was enhanced with increasing fertilizer rates being statistically superior with F_{250} over F_{100} level and control (Fig. 2). Intercropping illustrated a non-significant variance by sole sugarcane /sugar beet crops. Sole cropping gave higher weight of stripped cane and beet root than obtained from intercropped plants. Sami *et al*. (2018) investigated on the intercropping of sugar beet in sugarcane and also noted that weight of canes reduced significantly due to



	Sugar cane	Sugar beet
LSD 0.05 Organic amendments	0.09	0.14
LSD 0.05 Organic amendments - Intercropping	0.13	0.19
CV (%)	8.70	2.15

Fig. 2. The weight of sugar beet and single cane under sole and inter-cropping plantation with synergistic use of nitrogen fertilizer and organic amendments.



	Sngareane	Sugar beet
LSD 0.05 Organic amendments	5.01	8.04
LSD 0.05 Organic amendments × Intercropping	7.08	11.37
CV (%)	4.25	15.39

Fig. 3. Crop yield of sugarcane and sugar beet under sole and inter-cropping plantation with synergistic use of nitrogen fertilizer and organic amendments.

intercropping. Momentous increase of weight as a result of higher dose of fertilizer may be owing to the part of NPK role in the production of plant food photosynthetic and its translocation. Among the organic amendments, FM rendered the highest weight of sugar beet and single cane at both fertilizer rates. It has been shown that application of pig slurry (solid fraction) without composting resulted in the highest immediate P availability (Dhaliwal, 2016). The weight of sugar beet and single cane is akeyyield characteristic that directly influence the ultimate crop yield. This is improved proportionally with supply of plant nutrients to a certain limit. Synthetic NPK fertilizers meet only the macronutrient requirement, while micronutrients remain in short supply. Integration of NPK fertilizers with organic manures ensure the balanced supply of all plant nutrients, resulting in healthy plants and thus increased yield (Degefa *et al*., 2016).

Yield of stripped canes and beet roots. Data on per hectare yield (tonnes) of stripped canes and beet roots revealed that it was significantly affected by fertilizerdoses (Fig. 3).

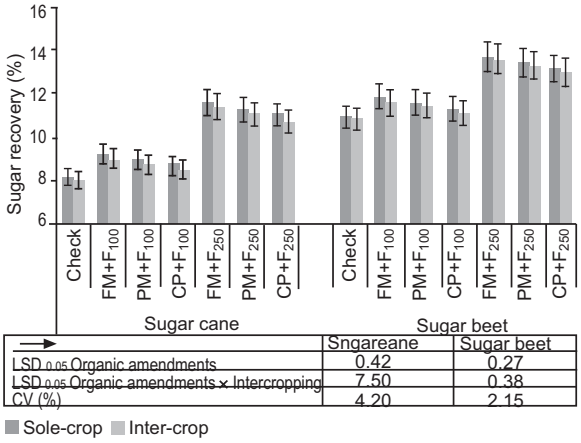
Intercropping exhibited non-significant difference with single cropping but their interaction with organic amendments was found significant. Sole crops fetched higher yields than from intercropped plants. The highest yields were recorded in F_{250} treatment under both sole and intercrop cultivation, which were followed by that under F_{100} with significant difference.

Treatments with higher dose of NPK in combination with FM attributed to better cane / beet root weight and its density which ultimately rendered higher cane and sugarbeet yields. In a similar study, Sami *et al*. (2018) determined that 95-95-95 Kg/ha NPK + 45 t/ha farmyard manure was the effective grouping for good sugar beet yield production.

Similarly, effect of phosphorus compost on previous crops was not as noticeable as that of farmyard manure and poultry manure, but then its residual outcome on following wheat grain yield was equivalent to FYM and Press Mud. Rehman *et al*. (2014) also indicated that stripped cane yield was higher in sole compared to intercropped sugarcane. Lessening in the yield of intercrops matched to their sole cropping is reimbursed with collective production of main and inter crops which increases the profits of farmers (Akter *et al*., 2004).

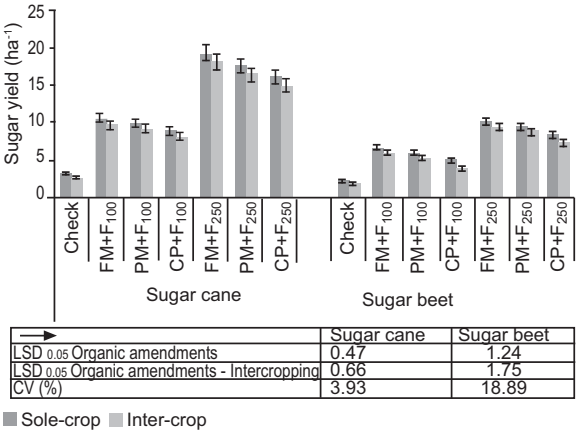
Sugar recovery from cane and beet. Sugar recovery (%) data of both crops showed that it was affected significantly by NPK doses and organic amendments, but intercropping showed the impact non-significant (Fig. 4). Sugar recovery shows larger values from sole sugarcane crop than that of intercropped plots. Larger sugar recovery was documented with F_{250} following by significant difference by F_{100} in both crops. Increasing trend in sugar recovery % age was observed with increasing fertilizer doses.

By way of increase in nutrient doses level improved the nutrient accessibility to plants. Consequently complimentary



	Sngareane	Sugar beet
LSD 0.05 Organic amendments	0.42	0.27
LSD 0.05 Organic amendments × Intercropping	7.50	0.38
CV (%)	4.20	2.15

Fig. 4. Sugar recovery percentage from sugarcane and sugar beet under sole and inter-cropping plantation with synergistic use of nitrogen fertilizer and organic amendments.



	Sugar cane	Sugar beet
LSD 0.05 Organic amendments	0.47	1.24
LSD 0.05 Organic amendments - Intercropping	0.66	1.75
CV (%)	3.93	18.89

Fig. 5. Sugar yield from sugarcane and sugar beet under sole and inter-cropping plantation with synergistic use of nitrogen fertilizer and organic amendments.

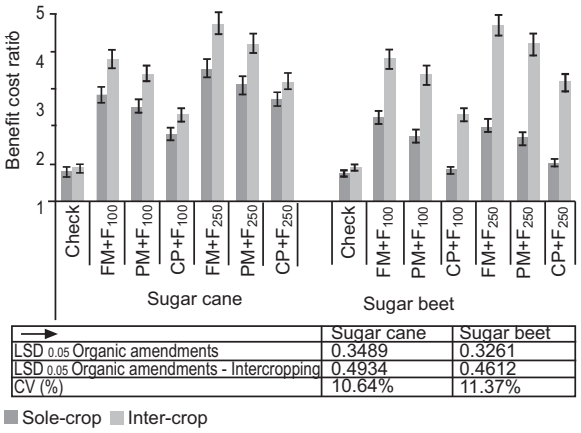
effect of N, P and K all the energy was consumed for aggregate magnitude of plant biomass in addition sugar recovery. These results conform to the findings of (Degefa *et al*., 2016), who stated rise in sugar production from sugarcane with increasing fertilizer / nutrients dose level. Similarly, sugarcane rendered higher values of sucrose percentage and sugar yield from sole crop than that intercropped with sugar beet (Sami *et al*., 2018). Among the organic amendments, FM rendered the highest sugar recovery percentage, while CP performed the lowest at both fertilizer doses. For decomposition of organic amendments, the share of non-biodegradable portions. The bio-accessible to micro-organisms organic fractions are the main factors affecting degradability and release of nutrients. It be influenced by several factors, such as hydrolytic action of the microbes, process period and the pre-degradation managements. Compost (CP) used in this study might be having less fraction of bioavailable organic matter that could cross the soil microbes cell membranes and is responsible for biodegradation and ultimately lesser release of plant nutrients occurred therein.

Total sugar yield. Sugar yield is the collaborative outcome of crop yield and sugar recovery (%). The statistical analysis of data on total sugar yield advocates that it was significantly increased by elevated levels of NPK but intercropping revealed non-significant difference by way of sole crop (Fig. 5). Among the organic manures, FM treated plots gave the highest sugar yield, while CP performed the lowest at both fertilizer doses.

Increase in sugar yield could be credited to complimentary effect of augmented nutrient accessibility and enhanced air flowand light capture which enriched photosynthetic efficacy and finally more crop yield. It resulted in momentous risedue to greater level of NPK nutrients fertilizer amount and nutrient augmented organic amendment FM. However, compost (CP) gave less sugar yield as compared to that from other two organic amendments. It could be due to slow release of nutrients from CP, which ultimately could not meet the nutrient requirement of the crops.

Bahadar *et al*. (2007) advocated that composting formed a slow release fertilizer, while Phosphorus availability being affected by abiotic and biotic factors. Increase in sugar beet and cane sugar yield with enhanced fertilizer levels was also indicated by Ullah *et al*. (2018).

Economic and benefit cost ratio. The pooled data of benefit cost ratio of two years was calculated for sugar beet and sugarcane to calculate the returns from investment (Fig. 6). The data unveiled that BCR was affected significantly by different levels of NPK fertilizers, organic manures and also intercropping. Its values increased in response to enhanced level of fertilizer applications, whereas intercropping system revealed higher BCR value compare to sole crop. The results presented momentous increase in BCR value



	Sugar cane	Sugar beet
LSD 0.05 Organic amendments	0.3489	0.3261
LSD 0.05 Organic amendments - Intercropping	0.4934	0.4612
CV (%)	10.64%	11.37%

Fig. 6. Economic turnouts from sugarcane and sugar beet production under sole and inter cropping plantation with synergistic use of nitrogen fertilizer and organic amendments.

due to greater amount of plant nutrients supply from organic and fertilizer sources. Bahadar *et al*. (2007)as well stated arise in BCR value of sugar beet with aggregate fertilizer levels. Enhanced economic benefit incurred through income from two crops cultivated in intercropping compared to sole crops system. Higher value of benefit cost ratio may be through improved crop growth and yield due to enhanced radiation and water use efficiencies (Ullah *et al*., 2018) and increased photosynthesis rates / enzyme activities. Value of two crops becomes higher compare to sole crop for the reason that greater pooled yield is succeeded with the effectual use of farm available resources in the intercrop model. Therefore, enhanced economic benefit incurred through income from two crops cultivated under intercrop compared to sole sugarcane crop system. Ramesh *et al*. (2000) also stated that an increase in BCR value of sugarcane crop with boosted fertilizer rates. Bahadar *et al*. (2007) calculated sugar beet as intercrop with sugarcane and its economic analysis indicated that income from sugarcane and sugar beet was higher than from sole crops. Therefore, sugar beet might be alternative most profitable and cost effective intercrop, if a suitable and proper infrastructure/setup for its processing and handling is established and this crop is cultivated on commercial scale with ease market facilities for its disposal.

Conclusion

Feasibility of sugarcane and sugar beet intercropping was worked out under integration of NPK fertilizer with organic amendments. The values of cane yield and sugar production traits were non-significantly curtailed and reduced because of intercropping in comparison to corresponding sole crops of sugarcane and sugar beet. Though, cumulative production and economic benefits from both the crops in intercropping systems were higher than sole cropping system. Thus, sugarcane growth and yield reductions due to sugar beet intercropping at lower fertilizer rate could be compensated by enhanced NPK fertilization at 250 Kg/ha, if integrated with farm yard manure even with better financial returns as compared to sole cropping.

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Conflict of Interest. The authors declare they have no conflict of interest.

References

Akter, N., Alim, M. A., Islam, M. M., Naher, Z., Rahman, M., Hossain, A.S.M.I. 2004. Evaluation of mixed cropping and intercropping of lentil and wheat. *Journal of Agronomy*, **3:** 48-51.

Bahadar, K., Sadiq, M., Subhan, M., Khan, A.U., Khan, P., Khan, D. 2007. Production potential of sugar beet intercropping with sugar cane under various planting geometry systems. *Pakistan. Sugar Journal*, **22:** 76-81.

Chandrakar, C.K., Prabha, N., Verma, O.N., Pandey, K.K. 2019. Standardization of planting geometry of sugarcane with suitable intercropping under drip irrigation in chhattisgarh plains. *International Journal of Current Microbiology and Applied Science*, **8:** 2878-2884.

Crookston, R.R., Hill, D.S. 1979. Grain yield and land equivalent ratios from intercropping corn and soybean in Minnesota. *Agronomy Journal*, **71:** 41-44.

Degefa, A., Bosie, M., Mequanint Y., Yesuf, E., Teshome, Z. 2016. Determination of crop water requirements of sugarcane and soybean intercropping at metahara sugar estate. *Advances in Crop Science and Technology*, **4:** 241.

Imam, S.A., Hossain, A.D., Sikka, L.C., Modomore, D.J. 1990. Agronomic management of potato/sugar-cane intercropping and its economic implication. *Field Crops Research*, **25:**111-122.

Khaliq, A., Naeem, A., Ahmad, H.B., Younus, M., Sher, R.U., Saeed, S., Hussain, I. 2021. Optimizing seed rates and effects of direct and indirect selection indices in sugarcane crop. *Indian Journal of Agriclture Research*, **55:**235-238. DOI:10.18805/IJARe.A-580.

Khaliq A., Ahmed, B.B., Nadeem, M.A., Mehmood, A., Ahmed, N., Yasin, M. 2020. Valuatiion of weed control methods by using inter row rotary weeder in sugarcance crop. *Indian journal of Agriclture Research*, **54:** 666-670.

Ofori, F., Stern, W.R. 1987. Cereal–legume intercropping systems. *Advance in Agronomy*, **41:** 41-90.

Ramesh, V., Varghese, S. 2000. Effect of fertilizer levels of N, P and K on the yield and juice quality of sugarcane. *Indian Sugar*, **50:** 301-302.

Rehman, A., Qamar, R., Qamar, J. 2014. Economic assessment of sugarcane (*Saccharum officinarum* L.) through intercropping. *Journal of Agricultural Chemistry and Environment*, **3:** 24-28.

Steel, R.G.D., Torrie, J.H., Dicky, D. 1997. *Principles and Procedures of Statistics*: *A Biometrical Approach* 3rd edition, P. 204-227, McGraw Hill Book. Co. Inc., Sigapore.

Sami, U., Khan, E.A., Ghulam, J., Mahjabeen, P., Noman. S. 2018. Surarcane sugar beet intercroping augments cumulative crop/sugar production and financial turn overs under enhanced fertilization. *Sugar Technology*, **20:** 431-438

Tahir, M., Khaliq, A., Waseem, M., Ali, A., Tanweer, T., Iqbal, R.H., Mohsin, A.U., Khan, M.A. 2011. Influence of different nitrogen application methods and sowing techniques on sunflower hybrid. *Legume Research*, *An International Journal*, **34:** 90-97.

Ullah, S., Khan, E.A., Jilani, G., Mahjabeen, P., Noman, S. 2018. Sugarcane Suger beet intercropping augments cumulative crop/suger production and financial turnovers under enhanced fertilization. *Sugar Technology*, **20:** 431-438

Wang, X., Feng, Y., Yu, L., Shu, Y., Tan, F., Gou, Y., Luo, S., Yang, W., Li, Z., Wang, J. 2020. Sugarcane/soybean intercropping with reduced nitrogen input improves crop productivity and reduces carbon footprint in China. *Science of the Total Environment*, **719:** 137517.

Waseem, M., Asghar, A., Tahir, M., Naeem, M., Ayub, M., Iqbal, A., Mohsin, A.U., Rehman, H.U., Ali, M., Ghaffari, A., Sarwar, M.A., Khaliq, A. 2012. Consequences of diverse use of nitrogen sources on grain yield, grain quality and growth attributes of hybrid maize (*Zea mays* L.). *African Journal of Biotechnology*, **11:** 13372-13386.