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Yield and Quality of Two Cultivars of Sugar Beet as Influenced by Fertilizer Applications

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Abstract. Studies were conducted to determine the effect of different doses of nitrogen and phosphorous applications on the yield and quality of two varieties of sugar beet. The genotypic varieties included in the study were: USH-10 and Maribo Extrapoli. Fertilizer doses applied were: 56.2, 113.7 and 170.0 (kg/ha) each of N and P. Results indicated that at the same leavel of fertilizer application, the two varieties did not differ significantly in root yield (kg/ha), sugar contents (%) and sugar yield (kg/ha). Yield, however, was significantly ($p < 0.01$) influenced by the application of different doses of N and P. The yield was the lowest for control (zero fertilizer application), and increased ($p > 0.01$) with the first two fertilizer doses. However, a decline in the yield ($p < 0.01$) was noted with the further higher dose of fertilizers. Sugar contents as percent yield did not differ in the two varieties. Fertilizer application resulted in significantly ($p < 001$) higher sugar level only upto the second dose. The results revealed that the second dose (113.7 : 113.7 kg/h of N : P) was the most economical level of fertilizer application for sugar beet crop cultivation in the agro-climatic region of Peshawar, Pakistan.

Keywords: sugar beet, fertilizer applications, sugar beet root yield, sugar beet sugar contents, sugar beet var. USH-10, sugar beet var Maribo Extrapoli

Introduction

Sugar beet (*Beta vulgaris*) is one of the most important sugar crops used for sugar production, in which regard it ranks second to sugarcane in the world. Sugar beet contains 30% more sugar than sugarcane and it is estimated that 40% of the total World's sugar is produced from sugar beet (Khan, 1969). The research and development work on the cultivation of sugar beet as a sugar crop in the North West Frontier Province (NWFP) of Pakistan was initiated in 1912. A major initiative, however, was undertaken in 1952. The earlier experiments showed that the climatic conditions of this part of the country were well suited for commercial production of this crop (Khan, 1969). NWFP is the only sugar beet producing province of Pakistan. Presently, sugar beet is sown on an area of 11.8 thousand ha in the province with a production of 456.3 thousand tonnes (Gop, 2006). Sugar beet, being a short seasoned crop, offers an excellent opportunity for better crop rotation and is well suited to the cropping system of the province. A much higher total net income per unit area can be obtained from sugar beet and the maize crops grown in a year than is possible from sugarcane (Kaffka *et al.,* 1994). Introduction of this crop in the region has been also beneficial for the sugar mills industry because of a longer crushing season, and hence more efficient utilization of labour and machinery. For these reasons, almost all sugar mills in the NWFP, Pakistan, had started the production of sugar from sugar beet as early as 1977. However, research work on the fertilizer requirements, cultural practices, evolution of varieties, and determining the yield potential of different varieties under different agro-climatic conditions has been sporadic and scanty. Present work, therefore, was undertaken to determine the optimum fertilizer requirements of two important varieties of sugar beet for maximum beet and sugar yields under the prevailing agro-climatic conditions of Peshawar valley.

Materials and Methods

A field experiment was conducted on clay-loam soil of Agricultural Research Institute, Tarnab, Peshawar, Pakistan, to determine the effect of different doses of nitrogen and phosphorus applications on the beet and sugar yield of two sugar beet varieties, namely, USH-10 and Maribo Extrapoli. Field was thoroughly prepared by adopting all the required tillage operations before sowing. Seeds were sown on ridges, 2 feet apart, followed by light irrigation. Eight irrigations were applied to the crop as and when required. The experiment was based on split plot design, with varieties kept in the main plot and fertilizer doses in sub-plots. Each treatment was replicated three times. The plot size was 4.88 x 7.62 m, with 7 rows in each treatment. Nitrogen and phosphorus were

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applied as urea and diammonium phosphate (DAP), respectively. DAP was applied before sowing, while urea was applied after first thinning in the second week of December. Three fertilizer treatments were given: T2 (56.2 : 56.2 kg/ha N and P), T3 (113.7 : 113.7 kg/ha N and P) and T4 (170 : 170 kg/ha N and P). No fertilizer application constituted the control, as T1 (0 : 0 kg/ha N and P). Data on root yield was recorded. Sugar content in the beets was determined according to method # 31-217 of AOAC (1984). Data were subjected to analysis of variance using M-Stat-C computer package (MSU, 1987). Means were separated using the Duncan's multiple range test (DMRT).

Results and Discussion

Characteristics of the soil of the experimental field are given in Table 1. The two varieties, at the same level of fertilizer application, did not differ significantly in root yield (Table 2). Average root yield was 44883.23 kg/ha for USH-10 and 41302.6 kg/ha for Maribo Extrapoli. However, root yield in both the varieties was significantly ($p < 0.01$) influenced by the application of different doses of N and P. Thus, both the varieties responded almost similarly to fertilizer applications at the respective same level. The average yield for control (no fertilizer application) in the application category T1 was the lowest (26475.33 kg/ha), which increased to a value of 45284.25 kg/ha with the first fertilizer dose category T2 (N and P = 56.2 kg/ha each), and to 53331.33 kg/ha with the second dose category T3 (N and P = 113.7 kg/ha each). However, a decline in the yield (47280.75 kg/ha) was noted with further incremental fertilizer application category T4 (N and P = 170.0 kg/ha each). The average beet root yield in UK is reported to be 30-37 tonnes/ha, which could become higher if uniformity of roots could be improved (Benjamin, 1987).

Table 1. Characteristics of the soil of the experimental field, Agricultural Research Institute, Tarnab, Peshawar, Pakistan

Particle size distribution (%)	
clay: 36	
silt: 42	
sand: 22	
Soil textural class	clay-loam
Moisture of oven-dried soil (%)	1.52
pH of the saturated soil paste	8.10
Organic matter (%)	0.80
Nitrogen (%)	0.09
Phosphorus, available as P_2O_5 (ppm)	28

Sugar contents of the beet roots were not statistically different in the two varieties at the same level of fertilizer application (Table 3). The average values were 14.22% for variety USH-10 and 14.90 % for Maribo Extrapoli. Sugar contents were, however, significantly ($p < 0.01$) influenced by the level of fertilizer application. With no fertilizer application (control, T1) the beet sugar contents were 13.51%. The value rose to 14.58% with the first fertilizer dose (T2) and to a level of 15.20% with the second dose (T3). However, with further increase in the fertilizer dose (T4) there was only a slight but statistically non-significant reduction in the beet sugar contents as compared with dose T3. The two genotypic varieties, therefore, responded almost similarly in this regard. The observations recorded during the present studies, regarding the sugar contents of sugar beet, corroborate results of the earlier studies (Kaffka *et al.,* 1994).

The mean sugar yield was the lowest in the control (T1), but responded significantly to fertilizer application (Table 4). With only slight numerical variations, the two genotypic varieties were similar in their response to fertilizer applications. The highest per hectare sugar yield (8092.0 kg) was recorded with

Table 2. Root yield of two sugar beet varieties, USH-10 and Maribo Extrapoli, under different doses of nitrogen (as urea) and phosphorus (diammonium phosphate) applications

fertilizer application category	Fertilizer dose nitrogen (kg/ha)	Fertilizer dose phosphorus (kg/ha)	Varieties USH-10 (kg/ha)	Varieties Maribo Extrapoli (kg/ha)	Mean* (kg/ha)
T1	0	0	28856.50	24094.16	26475.33^c
T2	56.2	56.2	44467.50	46101.00	45284.25^b
T3	113.7	113.7	55842.66	50820.00	53331.33^a
T4	170	170	50366.25	44195.25	47280.75^b
		Mean ^{ns}	**44883.23**	**41302.6**	

ns = non significant; * significant at 1% level; T1 = control

Table 3. Sugar content of two sugar beet varieties, USH-10 and Maribo Extrapoli, under different doses of nitrogen (as urea) and phosphorus (as diammonium phosphate) applications

Fertilizer application category	Fertilizer dose		Varieties		Mean* (%)
	nitrogen (kg/ha)	phosphorus (kg/ha)	USH-10 (%)	Maribo Extrapoli (%)	
T1	0	0	13.52	13.49	13.51[c]
T2	56.2	56.2	14.56	14.61	14.58[b]
T3	113.7	113.7	14.63	15.77	15.20[a]
T4	170	170	14.19	15.73	14.96[ab]
		Mean [ns]	**14.22**	**14.90**	

ns = non significant; * significant at 1% level; T1 = control

Table 4. Sugar yield of two sugarbeet varieties, USH-10 and Maribo Extrapoli, under different doses of nitrogen (as urea) and phosphorus (as diammonium phosphate) applications

Fertilizer application category	Fertilizer dose		Varieties		Mean* (kg/ha)
	nitrogen (kg/ha)	phosphorus (kg/ha)	USH-10 (kg/ha)	Maribo Extrapoli (kg/ha)	
T1	0	0	3901.4	3250.3	3575.9[d]
T2	56.2	56.2	6474.5	6735.4	6604.9[c]
T3	113.7	113.7	8169.8	8014.3	8092.0[a]
T4	170	170	7147.0	6951.9	7049.4[b]
		Mean [ns]	**6384.6**	**6154.1**	

ns = non significant; * significant at 1% level; T1 = control

the intermediate fertilizer application (T3), which fell significantly ($p < 0.01$) to 7049.4 kg with further increase in the fertilizer application dose (T4).

Nitrogen fertilization is required for profitable sugar beet production. However, sugar yield is sensitive to the timing of nitrogen availability, requiring ample amounts at the early crop stage for maximum vegetative growth, but also a period of nitrogen starvation prior to harvest for proper sugar accumulation in the storage roots. The level of sugar yield is a function of root yield and sucrose concentration, and is usually achieved at the fertilizer application rate that nearly corresponds to root yield. Thus higher the root yield, the higher the sugar production per hectare. However, the rate of sugar yield may be considerably less than the rate of fertilizer application required for the maximum total biomass production (roots plus tops) and is usually not the rate that gives the highest root sucrose concentration. It has been reported that application of 112 kg N/ha fertilizer application resulted in maximum sugar yield and maximized profit to the grower (Kaffka *et al.,* 1994).

Rational N fertilization is important to reduce adverse environmental impact of fertilization and to increase profitability in crop production (Bilbao *et al.,* 2004). For an efficient farming system, nutrient losses should be minimized and the ‘nutrient use efficiency (NUE)’ should be enhanced for maximizing economic returns and reducing environmental burden. A nutrient surplus, or deficiency, can lead to uneconomical cropping practice. Results of the present study suggest that application of N and P dose of 113 kg each was the best-suited dose for optimum NUE under the agro-climatic conditions of this region for the best yield results of sugar beet crop. Increase beyond this dose did not bring any significant gain, but was rather an uneconomical input.

It has been suggested that high nutrient surpluses are associated with high fertilizer applications (Langeveld and Overbosch, 1995), while an increasing share of sugar beets leads to lower surpluses. High nitrogen NUE is associated with optimum fertilizer applications. Sugar beet, however, combines high fertilizer applications with low surpluses and high NUE. Sugar beet is a much better converter of input energy into output energy as compared to wheat, and with each production intensity (defined as N fertilization level) the energy output in terms of beet yield increases (Kuesters and Lammel, 1999). However, the need for fertilizer application depends on the soil nutrient status and pre-plant soil N contents. This concentration allows one to distinguish between the N-responsive and non-responsive sites (Bilbao *et al.,* 2004). Unobserved soil characteristics can potentially interact with an input to make its effect on yield vary site-specifically within fields (Bullock *et al.,* 2002).

It can be concluded from the present study that the sugar beet cultivars respond well to N and P application both in terms of root yield and sugar contents. These results, however, are applicable to the crop grown in the region of the experiment. For other areas, region-specific fertilizer doses should be determined for different cultivars for efficient nutrient utilization and profitable sugar beet production.

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