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Quality, profitability, nutrient uptake and yield of maize (*Zea mays* L.) as influenced by treated sewage water and organic manure

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Abstract
An investigation was undertaken at Student Farm, CCS Haryana Agricultural University Hisar, Haryana (spring 2020) in split plot design to compute yield, quality, economics, N, P and K uptake by grain and straw of maize (*Zea mays* L.). There were two single cross hybrid (SCH) of maize and two irrigation source (IS) in main plots while four levels of organic manure (M) in subplots, each replicated thrice. Grain yield, protein content in grain, N, P and K uptake by grain and straw were recorded significantly higher by HQPM-1. Similarly, treated sewage water recorded significantly higher values of protein content in grain, N, P and K uptake by grain and straw, grain yield of maize. Interaction of SCH and I on grain yield were significant. HQPM-1 with treated sewage water recorded highest grain yield. Among organic manures, 100% RDN through vermicompost achieved higher quality content, yield, N, P and K uptake by grain and straw of maize. The interaction of SCH and M was found significant and HQPM-1 with 100% VC resulted highest grain yield. Overall, our results suggests that treated sewage water can be a potential replace to conventional water sources and 100% RDN through vermicompost can enhance the quality, yield, nutrient uptake in maize. However, higher economics was recorded under 100% RDN through FYM.

Keywords: FYM, maize, organic manure, protein, RDN and yield

Introduction

In India, rice-wheat is the main cropping system in Indo-Gangetic plains. Which has resulted in a number of issues such as soil degradation, over-exploitation of underground water. Maize (*Zea mays* L.) can be a replace in this system because of its wider adaptability and it can be well fit for intercropping too i.e. compatibility. In Haryana, the government is also supporting farmers if they substitute rice with maize during the *kharif* season. Significant changes from rice mono-culture to more profitable rice-maize or maize-wheat-moongbean systems have either occurred or are in the process of occurring (Yakadri *et al*. 2015) [22].

In past, maize was attempted with conventional management practices as an alternate crop to rice in rice-wheat system but it was not successful due to economic reasons. But in recent years the introduction of single cross hybrid (SCH) technology provided genotypic options for crop diversification. Maize also known as “queen of cereals” is an important crop after rice and wheat in India with a total area of 9.02 m ha, production of 27.71 m tonnes and average productivity of 3.07 t/ha (FAO 2019) [5]. Whereas in Haryana, the area, production, and productivity of maize were 6,000 ha, 19,000 tonnes, and 3167 kg/ha in the *Kharif* 2016-17, respectively (Indiastatharyana.com 2017) [9].

Water resources in India's arid and semi-arid regions have been steadily declining for decades due to over-exploitation of ground water. In most Indian cities, a sewage system is used, which includes an underground pipe system that collects waste water from homes and transports it to a treatment plant. In the modern era, human excreta is flushed with a large amount of water and its outlet is connected to the sewage system. Therefore, treated sewage water can be a valuable alternative source of irrigation for feeding a population with limited water resources. The use of this water also has the additional benefit of protecting the environment. A number of sewage water treatment plants are in operation, so a significant portion of this volume can be used for irrigation, resulting in economic and environmental benefits. The application of treated sewage water boosts crop yield and soil nutrient levels (Mhaske *et al*. 2018) [16].

Plants irrigated with treated sewage water grew and yielded more, as measured by plant height, number of leaves per plant, dry matter, leaf area per plant, grain yield, and fodder yield (Chandrikapure *et al*. 2017) [3].

Following India's green revolution, intensive agriculture practices have resulted in a variety of issues, including a decline in soil fertility, productivity, and organic matter content (Kachroo and Dixit 2005) [11]. Intensive crop cultivation requires a high dose of nutrients through fertilizer, a significant amount of irrigation, and the use of agro-chemicals, all of which contribute to environmental contamination and soil fertility depletion. From the last four decades, Overuse of chemical fertilizers such as N, P, and K has resulted in fertility imbalances and micronutrient deficiencies. If the imbalanced fertilizer dose is not corrected, the yield can stagnate or decrease. Therefore, adding organic sources of nutrients is critical for plant and field growth, yield, and quality. FYM application in maize can result in increased plant height, green forage yield, and dry matter yield (Chaudhari *et al*. 2017) [4]. Drought stress has a negative impact, but vermicompost can alleviates its deleterious effect on grain yields (Gholipoor *et al*. 2014) [7]. Application of vermicompost to soil improves soil health, nutrient status, enzymes, growth hormones and other factors. It is a good source of both macro and micro nutrients. Vermicompost is a good substitute for commercial fertilizers since it contains more nitrogen, phosphorus, and potassium than normal heap manure (Nasab *et al*. 2015) [19]. The present study focus on the effects of two single cross hybrid (HQPM-1 and HQPM-5), two irrigation source (CW and TSW) and four organic manure treatments on yield, quality, economics and nutrient uptake of maize.

Materials and Methods

A field experiment was conducted during the Spring 2020 at Student Farm of CCS Haryana Agricultural University, Hisar. Geographically, Hisar is situated in the semi-arid sub-tropics at $29^0$10’ N latitude, $75^0$46’ E longitude and at an altitude of 215.2 meter above mean sea level and have semi-arid climate receiving average annual rainfall of 350 to 400 mm. A maximum temperature of around 48^0C during summer months of May to July and temperature below freezing point accompanied by frost in winter months of December to January is common in this region. Meteorological parameters during cropping season were recorded at observatory of the Department of Agricultural Meteorology, CCS HAU, Hisar. The soil of experimental site was sandy loam in texture having an alkaline pH (8.01), EC (0.39 dS/m), Walkley-Black C (0.34%), $KMnO_4$ oxidizable N (105kg/ha), 0.5 M $NaHCO_3$ extractable P (15.4 kg/ha), 1 N NH_4OAC extractable K (302 kg/ha). The experiment on maize crop was conducted in split plot design having treatments of single cross hybrid’s (HQPM-1 and HQPM-5) and irrigation source’s (CW= Canal Water and TSW= Treated Sewage Water) as main plots and organic manure’s (No Manure= No manure or fertilizer, 100% FYM= 100% recommended dose of N through FYM, 100% VC= 100% recommended dose of N through vermicompost and 50-50% Both= 50% of recommended dose of N through FYM and 50% of recommended dose of N through vermicompost) in sub-plot. All the treatments were replicated thrice. Each experimental unit consisted of 6.0 m × 5.0 m plots. At recommended spacing of 60 cm × 20 cm, the seeds were sown deep (5cm) hand dibbling on February 26th, 2020. According to the treatments, the nutrients were applied at the time of field preparation for the crop. At maturity, the crop was harvested manually. The harvested cobs are than threshed to estimate the grain yield. In grain and straw, N was determined by Nessler reagent method, P by vanadomolybdophosphoric acid yellow color method and K by flame photometric method. The uptake was calculated using the following:

Nutrient uptake (kg/ha) in grain/straw = [% Nutrient content in grain/straw × grain/straw yield (kg/ha)]

Total uptake of N/P/K (kg/ha) = N/P/K uptake in grain + N/P/K uptake in straw

The protein content in grain was calculated by multiplying N content in grain with a coefficient factor of 6.25. The net returns were calculated by deducting the cost of cultivation from gross returns. The benefit: cost ratio was calculated by dividing the net returns with cost of cultivation. All the data recorded were analysed as per the standard statistical technique.

Results and Discussion

Nutrient Uptake

Single cross hybrids, irrigation sources (I) and organic manures (M) had significant effect on protein content, N, P, K uptake by straw, N and K uptake by grain of maize(Table 1 and 2). P uptake by grain of maize was significantly affected by single cross hybrids and organic manures. The higher protein content (8.923%), total (grain + straw) N, P and K uptake of 123.651, 26.848 and 105.239 kg/ha respectively was recorded in HQPM-1. The genetic makeup of plant play an important role in nutrient uptake. N and P are the constituents of protein forming compounds especially amino acids. The higher N and P uptake in HQPM-1 might be ascribed to this reason. While higher K uptake might be for maintaining the ionic balance in the plant. These findings are in conformity with Kumar (2016) [12] and Nagy (2009) [17]. Higher protein content (8.904%), total N, P and K uptake of 121.630, 23.320 and 103.462 kg/ha respectively was recorded in TSW treatment. This might be due to increased nutrient input and availability of nutrients in TSW plots as TSW have higher macro and micro-nutrient contents compared to canal water. Alawsy *et al*. (2018) [1], Mhaske and Nikam (2017) [18] and Alghobar and Suresha (2016) [2] also obtained similar results. The data also reveals that higher protein content (9.042%), total N, P and K uptake of 155.033, 34.908 and 134.628 kg/ha respectively was recorded under 100% VC treatment. Vermicompost is a superior quality compost made by earthworms. The vermicompost contains labile organic C like microbial biomass carbon in higher amount, which serve as readily available nutrients to the plant by the mechanism of solubilization and chelation. Scientists have confirmed this from various studies that vermicompost provide nutrient readily to crop due to its higher solubility and decomposition by microbial and enzymatic attack. While in FYM, its decomposition and release of nutrients is slow. This might be the reason for higher total N, P and K uptake under 100% VC. These results are consistent with Prasad (2019) [21] and Kumar *et al*. (2015) [13].

Table 1: Effect of sewage water and organic manure on the grain yield, protein content in grain, N, P and K uptake by grain of maize.

Treatment	HQPM-1			HQPM-5		
	Irrigation Source		Mean	Irrigation Source		Mean
	CW	TSW		CW	TSW	
	N Uptake (kg/ha)					
No Manure	20.297	22.097	21.197	16.367	18.000	17.183
100% FYM	99.607	104.510	102.058	93.827	96.663	95.245
100% VC	107.060	109.787	108.423	100.537	104.243	102.390
50-50% Both	102.463	105.100	103.782	96.410	100.057	98.233
Mean	82.357	85.373	83.865	76.785	79.741	78.263
CD (p=0.05)	SCH = 1.866	I = 1.866			M = 5.307	
	SCH × I = 2.639	SCH × M = NS			I × M = NS	
		SCH × I × M = NS				
P Uptake (kg/ha)						
No Manure	3.583	3.883	3.733	2.780	3.103	2.942
100% FYM	21.037	21.607	21.322	19.293	20.073	19.683
100% VC	23.357	23.690	23.523	22.237	22.570	22.403
50-50% Both	21.833	22.210	22.022	20.720	21.123	20.922
Mean	17.453	17.848	17.650	16.258	16.718	16.488
CD (p=0.05)	SCH = 0.539	I = NS			M = 1.433	
	SCH × I = NS	SCH × M = NS			I × M = NS	
		SCH × I × M = NS				
K Uptake (kg/ha)						
No Manure	4.290	4.697	4.493	3.393	3.767	3.580
100% FYM	21.933	23.010	22.472	20.857	21.437	21.147
100% VC	24.857	25.960	25.408	23.153	24.003	23.578
50-50% Both	23.010	23.920	23.465	21.840	22.747	22.293
Mean	18.523	19.397	18.960	17.311	17.988	17.650
CD (p=0.05)	SCH = 0.609	I = 0.609			M = 1.425	
	SCH × I = NS	SCH × M = NS			I × M = NS	
		SCH × I × M = NS				
Protein Content (%)						
No Manure	8.480	8.523	8.502	8.440	8.457	8.448
100% FYM	8.897	9.170	9.033	8.733	8.833	8.783
100% VC	9.083	9.167	9.125	8.877	9.040	8.958
50-50% Both	9.003	9.060	9.032	8.833	8.980	8.907
Mean	8.866	8.980	8.923	8.721	8.828	8.774
CD (p=0.05)	SCH = 0.100	I = 0.100			M = 0.164	
	SCH × I = NS	SCH × M = NS			I × M = NS	
		SCH × I × M = NS				
Grain Yield (kg/ha)						
No Manure	1495	1620	1558	1212	1329	1271
100% FYM	7000	7125	7063	6720	6839	6780
100% VC	7378	7480	7429	7090	7204	7147
50-50% Both	7118	7248	7183	6825	6961	6893
Mean	5748	5868	5808	5462	5584	5523
CD (p=0.05)	SCH = 120	I = 120			M = 389	
	SCH × I = 170	SCH × M = 551			I × M = NS	
		SCH × I × M = NS				

Table 2: Effect of sewage water and organic manure on the economics, N, P and K uptake by straw of maize.

Treatment	HQPM-1			HQPM-5		
	Irrigation Source		Mean	Irrigation Source		Mean
	CW	TSW		CW	TSW	
N Uptake (kg/ha)						
No Manure	8.373	9.140	8.757	6.493	7.363	6.928
100% FYM	47.083	51.167	49.125	42.877	45.220	44.048
100% VC	49.943	53.120	51.532	46.690	48.757	47.723
50-50% Both	48.187	51.267	49.727	44.997	46.553	45.775
Mean	38.397	41.173	39.785	35.264	36.973	36.119
CD (p=0.05)	SCH = 1.270	I = 1.270			M = 3.017	
	SCH × I = NS	SCH × M = NS			IS × M = NS	
		SCH × I × M = NS				
P Uptake (kg/ha)						
No Manure	1.613	1.830	5.455	1.313	1.437	4.318
100% FYM	10.827	11.337	32.407	9.743	10.550	29.830

100% VC	12.013	12.757	35.908	11.243	11.763	33.908
50-50% Both	11.323	11.887	33.623	10.843	10.743	31.715
Mean	8.944	9.453	9.198	8.286	8.623	8.455
CD (p=0.05)	SCH = 0.352	I = 0.352			M = 0.786	
	SCH × I = NS	SCH × M = NS			I × M = NS	
		SCH × I × M = NS				
K Uptake (kg/ha)						
No Manure	19.310	21.180	20.245	15.307	16.977	16.142
100% FYM	101.923	106.473	104.198	95.103	98.727	96.915
100% VC	111.353	112.667	112.010	107.253	109.260	108.257
50-50% Both	105.687	111.640	108.663	97.787	101.220	99.503
Mean	84.568	87.990	86.279	78.863	81.546	80.204
CD (p=0.05)	SCH = 1.566	I = 1.566			M = 5.898	
	SCH × I = NS	SCH × M = NS			I × M = NS	
		SCH × I × M = NS				
B:C Ratio						
No Manure	0.640	0.700	0.670	0.523	0.573	0.548
100% FYM	2.267	2.307	2.287	2.177	2.213	2.195
100% VC	1.920	1.950	1.935	1.847	1.877	1.862
50-50% Both	2.057	2.093	2.075	1.967	2.013	1.990
Mean	1.721	1.763	1.742	1.628	1.669	1.649
CD (p=0.05)	SCH = 0.035	I = 0.035			M = 0.115	
	SCH × I = NS	SCH × M = NS			I × M = NS	
		SCH × I × M = NS				

Economics

B:C ratio of maize was significantly affected by different single cross hybrids, irrigation sources and organic manure treatments (Table 2). The higher B:C ratio (1.742) was recorded in HQPM-1. TSW treatment recorded higher B:C ratio (1.716). The data also revealed that higher B:C ratio (2.241) was recorded in 100% FYM. This could be due to higher yield in these plots causing higher returns over the cost. These results are in conformity with Prasad (2019) [21] and Meena *et al.* (2012) [14].

Yield

The single cross hybrids, irrigation sources and organic manure effects on maize grain yield were significant during the experimentation (Table 1). The data of grain yield showed that higher grain yield (5808 kg/ha) was registered in HQPM-1. This might be due to genetic yield potential. The higher grain yield (5726 kg/ha) was recorded in TSW treatment. This could be due to increased nutrient inputs in TSW plots than CW irrigation, which favoured for the higher yield of maize. The single cross hybrid and irrigation source had significant effect on grain yield of maize. The highest maize grain yield was recorded in HQPM-1 with TSW followed by HQPM-1 with CW. These results are in close conformity with Chandrikapure *et al.* (2017) [3], Nahhal *et al.* (2013) [18], Galavi *et al*. (2009) [6] and Yaryan (2000) [23]. The data also revealed that highest grain yield (7288 kg/ha) was recorded in 100% VC treatment followed by 50-50% Both (7038 kg/ha) treatment which were 5.302% and 1.690% higher than 100% FYM treatment respectively. The interaction between single cross hybrid and organic manure showed significant effect on maize grain yield. The highest grain yield was observed in HQPM-1 with 100% VC. This might be due to the more supply of nutrients through respective organic manure. The organic manures have low C:N ratio (<10:1), hence due to mineralization provide nutrients; readily to the plant which ultimately play an important role in plant growth promotion whose results are reflected in the terms of yield. The organic manures improve physical properties like aggregation, water holding capacity, infiltration rate and soil structure, chemical properties like availability of nutrients by production of organic acids and chelation; biological properties like microbial biomass carbon and microorganism and enzymatic activity resulting in increased nutrient uptake causing higher yield. These results are in close conformity with Prasad (2019) [21], Gunjal and Chitodkar (2017) [8], Pathan (2005) [20] and Jayaprakash *et al*. (2003) [10].

Our study demonstrated that HQPM-1 recorded higher grain yield, protein content in grain, N, P and K uptake by grain as well as straw. TSW performed better in terms of quality, yield, nutrient uptake by maize. Interaction of SCH and I on grain yield were significant. HQPM-1 with TSW recorded highest grain yield. TSW can be a potential replace to conventional water sources which also have additional environment benefit. 100% VC improved the quality content, nutrient uptake and yield of maize. The interaction of SCH and M was found significant and HQPM-1 with 100% VC resulted highest grain yield. However, highest economics was achieved under 100% FYM.

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