



Plant density and fertilization in hybrid quality protein maize (*Zea mays*): Effects on the soil nutrient status and performance of succeeding wheat (*Triticum aestivum*) and productivity of cropping system

S L JAT¹, C M PARIHAR², A K SINGH³, B KUMAR⁴, B SINGH⁵ and D SAVEIPUNE⁶

ICAR-Indian Institute of Maize Research, New Delhi 110 012

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ABSTRACT

After introduction of hybrid under maize (*Zea mays* L.) cultivation in India it became competitive to rice and found suitable for crop diversification. Due to higher nutrient demand and differential plant type the hybrid needs modification in production technology especially for nutrient and plant geometry. So, this study was conducted in maize-wheat (*Triticum aestivum* L.) (MW) system in western Indo-gangetic plains in sandy loam soil for two consecutive years (2010-12) to explore best maize density and nutrient management in system in order to enhance soil nutrient status and productivity. The results showed that the application of the highest dose of nutrients in maize, i.e. 300: 45.9: 87.5 N:P:K kg/ha resulted in higher organic carbon, macro and micronutrient availability in soil while application of the lowest dose of fertilizer gave significantly higher CEC and available sulphur. Significantly higher CEC, organic carbon and available nutrients were observed in 66 000 plants/ha which gave significantly higher plant height and effective tillers in wheat. The growth and yield attributes of wheat, viz. plant height, effective tillers, spike length, spikelets/spike and spike weight in wheat were significantly higher with residual effect of 300: 45.9: 87.5 N:P:K kg/ha nutrient application in maize which were on par with 250: 39.9: 75.0 N:P:K kg/ha. Amongst the direct nutrient application in wheat significantly higher LCC, SPAD, plant height, effective tillers, spike length, spikelet/spike, and grain weight/spike were recorded with 125% RDF which were on par with RDF or 75% RDF. The better nutrition in maize compared to ad-hoc recommendations resulted in significant ($P < 0.05$) enhancement of system productivity by 17 to 19%. The direct application of nutrient in wheat gave 14 to 19 higher yield of wheat as well as 6 to 8% higher yield of the MW system. So, on the basis of two years study it was concluded that growing of maize with 66 000 plants/ha and 250:39.9:75 kg/ha N:P:K application followed by 90:19.8:24.0 kg/ha N:P:K application in wheat may be adopted for higher yield and soil nutrient status in western Indo-gangetic plains.

Key words: Chemical soil properties, Grain yield, Organic carbon

Plant density is an important determinant of maize (*Zea mays* L.) grain yield and its impact was observed world over (Kutka 2011, Ahmad *et al.* 2007, Malaviarachchi *et al.* 2007). In case of very high density, plants may bear barren cobs, smaller ears and become susceptible to lodging and attack of diseases. While in case of lesser planting density, grain yield per unit area may be low because of lesser number of cobs as this is non-tillering crop. However, the plant might bear the multiple cobs which again become cumbersome for harvesting and causes variation in the grain size in subsequent cob and ultimately fetches fewer prices in the market. Kutka (2011) reviewed the progress of the maize productivity and found that one of the major gain was due to the enhancement in planting density from

30 000/ha in 1930s (composite era) to 79 000/ha in 1980s (hybrid era). Shanti *et al.* (1997) found the response of the maize composite and hybrid up to 120 kg/ha N application in sandy loam soils while there was significant difference in the yield of composite and hybrid. Kumar and Dhar (2010) found that for getting the better productivity and returns from maize-wheat (*Triticum aestivum* L.) cropping system, 60 kg N/ha through farmyard manure along with cowpea green manuring and *Azotobacter* should be applied to early matured maize, followed by application of 60 kg N, 13 kg P, and 25 kg K/ha in wheat, which resulted in 50% NPK saving in wheat. The highest residual effect was found when early maturing hybrid of maize was supplied with 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* while application of 120 kg N + 26 kg P + 50 kg K/ha showed the superiority over 60 kg N + 13 kg P + 25 kg K in both maize and wheat.

Suri and Puri (1997) found that the application of farmyard manure and phosphorus in maize showed significant direct and residual effects on the 3 sequential crops. Analysis

^{1,2,4}Scientist (e mail: sliari@gmail.com, pariharcm@gmail.com, bhupender.iari@gmail.com), ³Principal Scientist (e mail: adityajadon1409@gmail.com), ⁵Farm Manager (e mail: bsinghboya@gmail.com), ⁶YP II (e mail: dsaveipune@gmail.com).

of soil after harvesting the maize crop showed a significant build up of organic carbon and available P in the plots treated with P and farmyard manure. The positive effect on soil fertility parameters by the application of nutrient in maize composite (Ganga Safed 2) were reported by Benerjee *et al.* (2006). The residual effect of nutrient applied to maize had been reported in wheat (Kumar and Ahlawat 2004, Kumar and Dhar 2010) while these were non-significant in gobhi sarson (Kumar and Thakur 2009). Singh and Sanghi (2006) reported the significant improvement in the yield and net returns of the applied nutrient up to 125% of recommended dose of fertilizers and densities up to 83 000 plants/ha maintained after 30 days after sowing on early maturity maize hybrids in clay loam soils of the Rajasthan. Ahamad *et al.* (2007) found that maize hybrid with plant density of 90 000 plants/ha and 120 kg P/ha is recommended for higher grain yield in agro-climatic condition of Peshawar in Pakistan. Malaviarachchi *et al.* (2007) found that it is economical to increase plant density up to 88 888 plants/ha for hybrid maize grown for grain purpose where profit is increased by at 200 kg/ha nitrogen, 100 kg/ha P₂O₅ and 50 kg/ha K₂O level. However, this density cannot be applied for maize grown for green cobs.

Nutrient management plays a key role in sustaining the productivity of this system, as both the crops are high nutrient-requiring ones and respond to higher nutrient levels supplied by chemical fertilizers. But deterioration in soil health along with more nutrient requirement of full season SCH to realize their attainable potential becomes issue of great concern in this scenario (Class *et al.* 2012). However, the full potential of the high yielding wheat cultivars could not be realized on the residual fertility after maize which ascertains that there is need to supply nutrients to wheat crop. The existing nutrient management practices are based on individual crop and in fact, there is meager information on cropping system-based nutrient management, particularly in maize-wheat cropping system. Therefore, an attempt was made to study of the direct and residual nutrient application effects with varying maize density on the soil properties and performance of wheat.

MATERIALS AND METHODS

The field experiment was conducted at the maize research farm, Indian Agricultural Research Institute, New Delhi (28.4° N, 77.1° E, 228.2 m a.s.l.). The soil of the experimental field was sandy loam having pH 7.8, organic carbon 0.53%, available N (249.1 kg/ha) phosphorus 24.3 kg/ha and available potassium 411.1 kg/ha. The treatment consisting of plant geometry of 60 000 (67 × 25 cm), 66 000 (67 × 22.5 cm) and 75 000 (67 × 20 cm) in three main plots and four fertility levels in the sub-plots comprising blanket state nutrient prescription [150: 26.2: 33.0 (N:P:K kg/ha)] along with three higher levels of nutrient application, i.e. 200: 32.8:62.5, 250: 39.9:75.0 and 300:45.9:87.5. All the treatments were replicated thrice in split-plot design. The maize hybrid HQPM-1 was sowed on 12th and 1st July during 2010 and 2011, respectively. Atrazine @ 1 kg

a.i./ha was sprayed as pre-emergence for weed control. The fertilizer N was applied in three -splits equal at 33% basal comprising 20% basal, 25% at V₄ stage, 30% at V₈ stage, 20% at V_T stage and 5% at GF stage. Wheat crop was planted in the field for estimation of residual effect as well as direct application of fertilizer nutrients to wheat. The wheat crop cv. HD 2967 was planted in November months of both the years into split-split plot design with three replication having four sub-sub plot treatments, viz. 0, 75, 100 and 125% of the blanket state recommended dose of fertilizer (RDF) i.e. 120:26.4:32.0 N:P:K kg/ha.

The data on the maize grain yield was recorded from a net plot size of 40 m² at 12% moisture content. After harvesting of the maize crop, soil samples were taken using tube auger from three sites in each plot in 0-25 cm soil profile. A composite sample of 500 ml was prepared by mixing all three samples and extracting soil from each plots composited sample. The soil was kept in the oven for 24 hours at 105 °C for drying. The soil samples were prepared after grinding and sieving through 0.2 mm sieve and parameters like pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) were analysed using standard procedure. The micronutrient like iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) were analysed using DTPA extraction method with halo cathode lamp of respective nutrient in atomic absorption spectrophotometer. The available sulphur and phosphorus were analysed by colorimetric method using double beam spectrophotometer. The available nitrogen was estimated using Alkaline Potassium Permanganate method. While potassium was estimated through flame photometry using standard procedure.

The succeeding wheat growth parameters like plant height, leaf colour chart (LCC) and SPAD values were taken from five places in each plots at 80 days after sowing (DAS) of the crop and then averaged for getting value of each treatment. The tillers were counted from three places in each plot and averaged to get value of effective and total tillers in a plot just before harvesting. A total of 10 spikes were taken from each plot at the time of harvesting to estimate the yield attributing characters like spike length, spikelets/spike, 1 000-grain weight and grain weight/spike. The wheat grain yield was taken from 10 m² net plot areas and reported at 12% moisture content.

The results obtained were analyzed using SAS 9.3 software to determine treatment effects (SAS Institute, Cary, NC). Tukey's honestly significant difference test was used as a post hoc mean separation test (P<0.05).

RESULTS AND DISCUSSION

Residual effects on soil properties

EC, pH, CEC and organic carbon in the soil: The application of the nutrients in quality protein maize hybrids resulted in the non-significant variation in the pH and EC of the soil while significant variation was found in the organic carbon and CEC of the soil (Table 1). The CEC was the

highest with lowest nutrient levels which decreased with progressive increase of the fertility levels. This might be due to progressive increase of N and K fertilizers levels in the crop results in the more sorption and adsorption and ultimately reduces the available sites for exchange of cation. The plant population in maize resulted in non-significant effect on the pH and EC but resulted in significant effect on organic carbon and CEC of the soil which were found higher with the 66 000 plants/ha. The optimum population resulted in proper utilization of the soil resources which ultimately resulted in higher positive residual effect. The higher above and below ground biomass production in maize by optimum population and improved nutrition might have resulted in enhanced organic carbon in these treatments due to enhanced microbial activity in soil. The similar findings of higher nutrition based improvement in soil organic carbon was also reported by Kumar *et al.* (2015).

Table 1 Effect of plant population and fertility levels on the soil chemical properties after harvest of maize (Pooled data of two years)

Treatment	pH	EC (dS/m)	CEC (me/1000 g soil)	Organic carbon (%)
<i>Plant population/ha</i>				
60000	7.76a	0.20a	20.42b	0.56b
66000	7.80a	0.21a	21.68a	0.64a
75000	7.77a	0.20a	19.03c	0.56b
p value	0.091	0.093	0.0002	0.0016
HSD (P=0.05)	NS	NS	0.73	0.04
<i>Fertility levels (N: P:K kg/ha)</i>				
150: 26.2: 33.3	7.72a	0.19b	22.68a	0.50b
200: 32.8: 62.5	7.81a	0.20ab	21.11b	0.59a
250: 39.9: 75.0	7.82a	0.20ab	19.04c	0.63a
300: 45.9: 87.5	7.77a	0.21a	18.68c	0.63a
p value	0.08	0.0043	<.0001	<.0001
HSD (P=0.05)	NS	0.01	0.47	0.04

*Means followed by the different letters in each column are significantly different using Tukey's HSD at P = 0.05.

Macronutrient status of the soil

The application of the nutrients in quality protein maize hybrids resulted in the non-significant variation in the N and S of the soil while significant variation was found in the N, P and K status of the soil (Table 2). The N, P and K status in the soil were the highest with the highest nutrient levels which decrease in fertility levels. This might be due to progressive increase of P and K fertilizers levels in the crop results in the more availability of these nutrients in the soil as approximately 20% of applied P and 40% of applied K is utilized by first crop. The plant population in maize resulted in non-significant effect on the N and S status in the soil but resulted in significant effect on P and K in the soil which were found higher with the 66000 plants/ha

Table 2 Effect of plant population and fertility levels on the soil macronutrient balance after harvest of maize (Pooled data of two years)

Treatment	Available N(kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available S (kg/ha)
<i>Plant population/ha</i>				
60000	258.5b	23.22c	411.4b	19.04a
66000	269.7a	32.25a	455.0a	18.88a
75000	257.2b	27.99b	467.6a	20.08a
p value	0.0006	<.0001	0.0003	0.024
HSD (P=0.05)	4.95	0.37	17.61	1.29
<i>Fertility levels (N: P:K kg/ha)</i>				
150: 26.2: 33.3	261.1b	25.2c	404.4d	20.52a
200: 32.8: 62.5	263.4b	26.47b	439.4c	19.18bc
250: 39.9: 75.0	250.9c	29.94a	459.6b	17.93c
300: 45.9: 87.5	271.8a	29.64a	475.3a	19.71ab
p value	<.0001	<.0001	<.0001	0.0002
HSD (P=0.05)	4.84	0.49	3.56	1.3

*Means followed by the different letters in each column are significantly different using Tukey's HSD at P = 0.05.

in case of P and 75000 plants /ha with respect of K. The optimum population resulted in proper utilization of the soil resources which ultimately might resulted in higher positive residual effect. The better nutrition in maize led enhancement of available major nutrient in soil was also reported in earlier findings (Banerjee *et al.* 2006, Dhar and Kumar 2010, Kumar *et al.* 2015).

Micronutrient status of the soil

A significant variation was found in the soil Zn and Cu availability with varying fertility levels and planting densities (Table 3). It was found that the application of 250: 39.9: 75.0 kg/ha of N:P:K resulted in the lowest availability of the Zn and Cu due to higher grain yield. However, there was significant interaction was found with respect to soil Zn and Cu status among nutrient levels and planting densities. Fertility levels and planting densities are two most important considerations for agronomic practice in maize cultivation. It shows that Zn and Cu are two most important micronutrient for the maize hybrids commercial production which must be altered for higher and sustainable maize production. However, such effect of this magnitude of these treatments were not seen in respect of soil Fe and Mn availability in the soil. As a residual effects of the applied nutrient the highest contents of organic C; and available N, P, K and Zn were found from the soil supplied with 20 tonnes farmyard manure + 5 kg zinc/ha, followed by 120 kg N + 10 tonnes farmyard manure/ha for N, recommended dose of fertilizer for P and 10 tonnes farmyard manure + 5 kg zinc/ha for K, Zn and organic carbon (Karki *et al.* 2005).

Effects on wheat

Growth parameters: The LCC, SPAD and plant height

Table 3 Effect of plant population and fertility levels on the soil micronutrient balance after harvest of maize (Pooled data of two years)

Treatment	Micronutrient in the soil (mg/kg of soil)			
	Zn	Fe	Cu	Mn
<i>Plant population/ha</i>				
60000	7.44a	11.58b	5.23b	18.86a
66000	6.34b	12.26a	6.37a	18.95a
75000	5.61c	11.78b	5.36b	18.24b
p value	<.0001	0.0004	<.0001	0.0105
HSD (P=0.05)	0.23	0.23	0.28	0.6
<i>Fertility levels (N: P:K kg/ha)</i>				
150: 26.2: 33.3	5.88c	11.23b	5.8b	18.37c
200: 32.8: 62.5	6.47b	12.44a	5.89b	18.81ab
250: 39.9: 75.0	5.90c	11.37b	4.03c	19.06a
300: 45.9: 87.5	7.60a	12.47a	6.88a	18.48bc
p value	<.0001	<.0001	<.0001	0.0001
HSD (0.05)	0.32	0.31	0.28	0.36

*Means followed by the different letters in each column are significantly different using Tukey's HSD at P = 0.05.

are the indicator of the plant health were measured in wheat at 80 days after sowing (Table 4). The data showed that LCC and SPAD values in succeeding wheat were non-significantly affected by the residual effect of the nutrient applied to maize but direct affect of the nutrient application in wheat showed significant difference. The higher SPAD values were obtained with progressive increase in the nutrient levels which was significantly on par at all level compared to the lowest level as residual effect. However, among the direct application of the nutrient 125% RDF resulted in higher SPAD and LCC values which were at par to RDF. The plant height and tillers were also significantly influenced by the residual effects of the treatments applied to maize as well as by the direct nutrient application. The 66 000 plants/ha density in maize gave higher wheat plant height which was on par to the highest density and was significantly superior over lowest density. The tallest plant was observed in highest nutrient levels applied to maize crop as a residual effect. The taller plants were obtained with increasing nutrient levels both in case of direct and residual effects. However, the plant height was higher with 100% RDF which was on par to 125% RDF. The effective tillers in wheat were significantly higher with application of 250: 39.9: 75.0 kg/ha of N:P:K in maize and 125% RDF application in wheat. However, these were on par with highest nutrient applied in maize and 75 of 100% RDF applied in wheat. The tillers and their effectiveness contribute directly towards the yield in the wheat crop. The better nutrition due to either higher nutrient availability as residual effect or by direct application of nutrient in wheat resulted in good crop health due to increase in chlorophyll content. Thus, more photosynthesis in these treatments might have enhanced the tillers, plant height and greenness

Table 4 Direct and residual effects of fertility levels and plant geometry on the growth parameters of the wheat (Pooled data of two years)

Treatment	LCC at 80 DAS	SPAD at 80 DAS	Plant Height at 80 DAS (cm)	Tillers/m ²	
				Total tillers	Effective tillers
<i>Crop geometry in maize</i>					
60000	4.57	45.04	98.01b	392.03	360.25b
66000	4.54	44.23	99.98a	424.50	403.13a
75000	4.58	44.46	99.58a	410.66	384.66ab
p value	0.8817	0.4141	0.0214	0.1291	0.0453
HSD (0.05)	NS	NS	1.54	NS	39.87
<i>Residual fertility levels in maize (N:P:K kg/ha)</i>					
150: 26.2: 33.3	4.53	44.27	94.57b	354.00c	331.21c
200: 32.8: 62.5	4.53	44.40	100.19a	374.38b	348.38b
250: 39.9: 75.0	4.58	45.00	100.07a	451.13a	426.50a
300: 45.9: 87.5	4.61	44.63	101.93a	456.75a	424.63a
p value	0.5267	0.4675	<.0001	<.0001	<.0001
HSD (0.05)	NS	NS	2.42	15.05	14.09
<i>Direct nutrient application to wheat</i>					
Control	4.35b	42.35b	98.36b	395.25b	369.88b
75% RDF	4.71a	45.58a	98.61ab	407.08ab	381.71ab
RDF	4.56a	45.01a	99.90a	407.75ab	381.79ab
125% RDF	4.63a	45.35a	99.89a	426.17a	397.33a
p value	0.0006	0.0007	0.0078	0.0053	0.0093
HSD (0.05)	0.20	2.00	1.47	22.13	20.63

*RDF=120:26.4:32.0 N:P:K kg/ha. Means followed by the different letters in each column are significantly different using Tukey's HSD at P = 0.05.

indices of LCC and SPAD in wheat. The similar finding of higher yield attributes and greenness indices in wheat due to better nutrition was also reported by Mohanty *et al.* (2015).

Yield attributes: The yield attributes in the wheat were significantly influenced by the residual fertility status and the direct application of the nutrients (Table 5). The spike length, spikelets/spike, grains/spike and grain weight/spike was the highest with the highest level of the nutrient applied to maize as a residual effect. It shows that there is significant effect of the maize nutrition on the succeeding wheat's yield attributes. Likewise, a significant improvement in these entire yields attribute was found with the application of the 125% RDF in wheat which was at part to the RDF application. However, there was not much impact on the 1 000-grains weight of the wheat which shows there is more genetic contribution in this trait as compared to nutrition except direct application of the nutrients. The similar findings of enhancement of yield attributes in wheat as result of better nutrition was also reported by Mohanty *et al.* (2015) in similar ecologies.

Table 5 Direct and residual effects of fertility levels and plant geometry on the yield attributes of the wheat (Pooled data of two years)

Treatment	Spike length (cm)	Spikelet/spike	Grains/spike	1000-grains weight (g)	Grain weight/spike (g)
<i>Crop geometry in maize</i>					
60000	9.42	17.28	40.45	20.75	1.73
66000	9.46	16.93	40.24	20.56	1.79
75000	9.54	17.13	42.71	20.69	1.87
p value	0.6615	0.5325	0.3638	0.3645	0.2203
HSD (0.05)	NS	NS	NS	NS	NS
<i>Residual fertility levels in maize (N:P:K kg/ha)</i>					
150: 26.2: 33.3	9.30b	16.65b	40.78	20.83	1.71b
200: 32.8: 62.5	9.43ab	16.85b	40.33	20.88	1.79ab
250: 39.9: 75.0	9.43ab	17.50a	41.17	20.21	1.80ab
300: 45.9: 87.5	9.72a	17.45a	42.24	20.75	1.88a
p value	0.0094	0.0007	0.4257	0.0912	0.0123
HSD (0.05)	0.31	0.57	NS	NS	0.13
<i>Direct nutrient application to wheat</i>					
Control	9.45bc	16.68b	40.83ab	20.67	1.72b
75% RDF	9.18c	16.79b	38.93b	20.75	1.79ab
RDF	9.48b	17.32a	42.54a	20.67	1.82ab
125% RDF	9.78a	17.66a	42.22a	20.58	1.86a
p value	<.0001	<.0001	0.0002	0.6835	0.0026
HSD (0.05)	0.28	0.49	2.21	NS	0.10

*RDF=120:26.4:32.0 N:P:K kg/ha. Means followed by the different letters in each column are significantly different using Tukey's HSD at P = 0.05.

Effects on yield

Wheat: Significantly higher yield of wheat was obtained as residual effect of treatment applied in maize having either 66000 or 75000 plants/ha during both the years (Table 6). The higher nutrient availability due to more biomass production in these treatments might result in higher wheat yields by improvement of its some of the growth and yield attributes. The appropriate plant population cropping system is key for higher productivity especially in maize system. The residual effects on wheat crop showed that the application of 200: 32.8: 62.5 kg/ha N:P:K in maize resulted into significantly higher grain yield of wheat. Significant residual effects of these treatments applied in maize on higher nutrient availability found in our study might given better crop health which in turn might have enhanced the wheat yield. Among the direct application to wheat the highest grain yield was registered with 125% RDF which was on par to RDF. The application of 75, 100 and 125% RDF in wheat resulted in 11, 14 and 19% yield enhancement over control. The better crop nutrition as evidenced by enhanced crop growth parameters in these treatments might have resulted in better source-sink relationship which resulted in

Table 6 Direct and residual effects of fertility levels and plant geometry on the yields of the maize-wheat cropping system

Treatment	Wheat		System		Pooled
	2010-11	2011-12	2010-11	2011-12	
<i>Crop geometry in maize</i>					
60000	4728b	4752b	10307b	10488a	10398b
66000	5195a	5062ab	11368a	10912a	11140a
75000	5383a	5260a	11282a	10600a	10952ab
p value	0.0011	0.0440	0.0159	0.0891	0.0399
HSD	222.4	470.6	797.29	NS	687.5
<i>Fertility levels in maize (N:P:K kg/ha)</i>					
150: 26.2: 33.3	4399c	4862b	9307b	9823b	9565b
200: 32.8: 62.5	5638a	5343a	11708a	10655a	11181a
250: 39.9: 75.0	5207ab	4957ab	11428a	11329a	11379a
300: 45.9: 87.5	5166ab	4936ab	11500a	10890a	11195a
p value	<0.001	0.0224	<0.001	0.0003	<0.001
HSD	478.9	427.4	336.0	777.0	414.9
<i>Direct nutrient application to wheat</i>					
Control	4594c	4525c	10350c	10103c	10226c
75% RDF	5132b	4984b	10223b	10627b	10825b
RDF	5217ab	5204ab	11129ab	10880ab	11004ab
125% RDF	5466a	5386a	11441a	11087a	11064a
p value	<.0001	<0.001	<0.009	<0.0001	<0.0001
HSD	160.7	222.6	322.6	256.9	227.7

*RDF=120:26.4:32.0 N:P:K kg/ha, Means followed by the different letters in each column are significantly different using Tukey's HSD at P = 0.05.

higher wheat productivity. The enhanced nutrition effects on the yield increment of wheat and system was reported in earlier findings of similar ecology by Dhar and Kumar (2010), Jat *et al.* (2013) and Mohanty *et al.* (2015).

System: The plant population in maize and nutrient management in both the crops significantly affected the system yield of maize-wheat rotation. The significantly (P=0.05) higher two year pooled system yield was obtained with planting of maize in 66000 plants/ha which was at par with 7500 plants/ha. However, there was no difference in system yield due to maize plant population during second year. The application of higher doses of nutrient above the ad-hoc recommendations resulted in significant improvement in system yield and was highest with application of 250:32.8:62.5 kg/ha N:P:K in maize. There were no significant differences amongst better nutrient levels applied in maize on system yield. The improvement in pooled system yield due to higher nutrient levels in maize over ad-hoc recommendation was 17 to 19%. The better nutrition to maize and higher residual soil nutrient status might have improved the crop health which finally culminated as better source sink relationship and thus gave

higher grain yield. The application of nutrients in wheat as 125% of RDF resulted in significantly higher system yield and was at par with 100% RDF. However, 100% RDF was also statistically similar with those of 75% RDF application in wheat and these three RDF levels in wheat improved system productivity by 6 to 8%. The similar results were also reported by Kumar and Dhar (2010) while working in maize-wheat rotation in similar ecologies.

Based on two years study it can be concluded that long duration quality protein hybrids shall be planted with 66,000 plants/ ha with 200:32:8:62.5 kg N:P:K/ ha followed by application of 75% RDF in wheat to ensure higher soil nutrient status and productivity of system.

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REFERENCES

- Ahmad M, Hussain N, Jan A, Ahmad K and Hussain S. 2007. Response of maize to phosphorus levels and plant density. *Sarhad Journal of Agriculture* **23**(1): 69–74.
- Banerjee M, Rai R K, Maiti D and Dhar S. 2006. Impact of chemical fertilizers and biofertilizers on the yield and fertility build-up of soil under maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Sciences* **76**(12): 753–5.
- Dass S, Kumar A, Jat S L, Parihar C M, Singh A K, Chikkappa G K and Jat M L. 2012. Maize holds potential for diversification and livelihood security. *Indian Journal of Agronomy* **57**(3rd IAC Special Issue):32–7.
- Jat S L, Parihar C M, Singh A K, Jat M L, Sinha A K, Mishra B N, Meena H, Paradkar V K, Singh C S, Singh Dilip and Singh R N. 2013. Integrated nutrient management in quality protein maize (*Zea mays*) planted in rotation with wheat (*Triticum aestivum*): Effect on productivity and nutrient use efficiency under different agro-ecological conditions. *Indian Journal of Agricultural Sciences*. **83**(4):391–6.
- Karki T B, Kumar A and Gautam R C. 2005. Influence of integrated nutrient management on growth, yield, content and uptake of nutrients and soil fertility status in maize (*Zea mays*). *Indian Journal of Agricultural Sciences* **75**(10): 682–5.
- Kumar A and Thakur K S. 2009. Effect of intercropping *in-situ* green manures and fertility levels on productivity and soil nitrogen balance in maize (*Zea mays*)-gobhi sarson (*Brassica napus*) cropping system. *Indian Journal of Agricultural Sciences* **79**(9): 758–62.
- Kumar A and Dhar S. 2010. Evaluation of organic and inorganic sources of nutrients in maize (*Zea mays*) and their residual effect on wheat (*Triticum aestivum*) under different fertility levels. *Indian Journal of Agricultural Sciences* **80**(5): 364–71.
- Kumar V and Ahlawat I P S. 2004. Carry over effect of biofertilizers and nitrogen applied to wheat (*Triticum aestivum* L.) and direct applied N in maize (*Zea mays* L.) in wheat-maize cropping system. *Indian Journal of Agronomy* **49**(4): 233–6.
- Kumar V, Singh A K, Jat S L, Parihar C M, Pooniya V, Singh B and Sharma S. 2015. Precision nutrient and conservation agriculture practices for enhancing productivity, profitability, nutrient-use efficiencies and soil nutrient status of maize (*Zea mays*) hybrids. *Indian Journal of Agricultural Sciences* **85**(7): 926–30.
- Kutka F. 2011. Open-pollinated vs. hybrid maize cultivars. *Sustainability* **3**: 1531–54. doi:10.3390/su3091531.
- Malaviarachchi M A P W K, Karunarathne K M and Jayawardane S N. 2007. Influence of plant density on yield of hybrid maize (*Zea mays* L.) under supplementary irrigation. *Journal of Agricultural Sciences* **3**(2):58–66.
- Mohanty S K, Singh A K, Jat S L, Parihar C M, Pooniya V, Sharma S, Sandhya, Chaudhary V and Singh B. 2015. Precision nitrogen-management practices influences growth and yield of wheat (*Triticum aestivum*) under conservation agriculture. *Indian Journal of Agronomy* **60**(4):86–90.
- Shanti K, Rao V P, Reddy M R, Reddy M S and Sarma P S. 1997. Response of maize (*Zea mays*) hybrid and composite to different levels of nitrogen. *Indian Journal of Agricultural Sciences* **67**(9): 424–5.
- Singh D and Sanghi S M. 2006. Response of early maturing maize (*Zea mays*) hybrids to applied nutrients and plant densities under agroclimatic conditions of Udaipur in Rajasthan. *Indian Journal of Agricultural Sciences* **76**(6): 372–4.
- Suri V K and Puri U K. 1997. Effect of phosphorus application with and without farmyard manure on rainfed maize (*Zea mays*) - wheat (*Triticum aestivum*) - maize sequence. *Indian Journal of Agricultural Sciences* **67**(1): 13–5.