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Quantitative and Qualitative Implications of Plant Density and Nitrogen Management in Quality Protein Maize (*Zea mays* L.)

A.S. Bisht[1], Amit Bhatnagar[2*], Anil Shukla[3] and Veer Singh[4]
[1,2,3]Department of Agronomy,[4]Department of Soil Science
G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263145

A field experiment was laid out in a factorial randomized block design with three replications at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Fifteen treatment combination consisting of three plant densities; viz., 66,666 ; 83,333 and 1,00,000 plants ha-1 and five mode of nitrogen nutrition, viz., 100% recommended dose of NPK through chemical fertilizer (RDF); 125 % RDF; 100 % recommended dose of nitrogen (RDN) through inorganic + 25 % RDN through organic; 75 % RDN through inorganic + 25 % RDN through organic and 50 % RDN through inorganic + 50 % RDN through organic were tested to study their effect on lysine, tryptophan contents and grain yield of QPM (quality protein maize). The results revealed that an increase in plant density up to 83,333 plant ha-1 led to significantly higher grain yields and low protein content without significant reduction in quality i.e. lysine and tryptophan contents. All the nutrient management practices remained at par to each other for all the parameters studied.

Key words: Maize, Nitrogen, Plant density, Protein, Quality, Yield

Maize is one of the major sources of carbohydrate and protein. Maize grains accounts for about 15 to 56% of the total daily calories of people in about 25 developing countries, particularly in Africa and Latin America (FAO, 1992). However, an impor-tant nutritional limitation of maize endosperm protein is its amino acid balance. Deficiency in certain amino acids reduces the availability of the others present in abundance. Protein quantity in a normal maize grain is low (80-110 g kg^{-1}) and of poor in quality because of low levels of lysine and tryptophan (Bjarnason and Vasal, 1992). This may cause nutritional deficiencies when used as an exclusive protein source (Glover and Mertz, 1987). With discovery of the recessive Opaque-2 (o2) mutant the content of the essential amino acids *viz*., lysine and tryptophan can be increased to double. However, *o2* maize has opaque, chalky and soft endosperm, which makes it undesirable (Prasanna, *et al*., 2001). These *o2* inadequacies have been addressed by *o2* genetic endosperm modifiers, which have been used to convert the soft *o2* maize into hard and translucent type called 'Quality Protein Maize' (QPM). It has hard and vitreous endosperm, high nutritional quality and normal yield (Moro *et al.*, 1996). It produces quality protein without sacrificing carbohydrates and calories.

Many production factors that increase grain yield also increase the starch concentration, while reducing the grain protein level (Mcdermitt and Loomis, 1981). Maintaining yield without sacrificing the protein quantity and quality is an important aspect for QPM.

Plant density is one such important parameter, which affects the yield of maize. However, increasing plant population does not always result in enhanced maize grain yields, rather consistently reduce protein concentration as reported by Ahmadi *et al*. (1993). Vyn and Tollenaar (1998) observed an inverse relationship between maize grain yield and protein concentration due to plant population. Thus, maintenance of optimum plant density is an important aspect to sustain grain yield without affecting protein quality.

Nitrogen management is another important factor, which affects protein content and grain yield. The protein quality i.e. amino acids contents and important N-containing compounds in plant biomass are affected by N nutrition (Neuberg *et al.*, 2010 and Pavlík *et al.*, 2010). However, the amount of fertilizer nitrogen required to produce maximum grain protein content is not the same as the amount that will maximize grain yields (Sander *et al*., 1987). Therefore, keeping the above facts in view, a field experiment was conducted to find out the optimum plant density and proper nitrogen management for QPM in respect of protein quality and grain yield.

Materials and Methods

The field experiment was conducted during spring (February-June) season in sandy loam

*[2]Corresponding author email : bhatnagaramit75@gmail.com

hyperthermic *Aquic Hapludoll* soil under humid sub – tropical climate with an average annual rainfall of 1433 mm, of which, more than 85% was received during June to September. The soil was neutral (pH 6.9), rich in organic carbon (1.18 %), low in available nitrogen (212.3 kg ha^{-1}), medium in available phosphorus (18.14 kg ha^{-1}) and available potassium (258.2 kg ha^{-1}). The treatment combinations consisted of three plant densities *viz*., 66,666; 83,333 and 1,00,000 plants ha^{-1} maintained through 60 × 25 cm, 60 × 20 cm and 50 × 20 cm spacing, respectively and five modes of nitrogen nutrition *viz*., 100% recommended dose of NPK through chemical fertilizers (RDF); 125 % RDF; 100 % recommended dose of nitrogen (RDN) through inorganic + 25 % RDN through organic; 75 % RDN through inorganic + 25 % RDN through organic and 50 % RDN through inorganic + 50 % RDN through organic were tested in factorial randomized block design, replicated thrice. The recommended doses for N, P_2O_5 and K_2O were 120, 60 and 40 kg ha^{-1}, respectively. The source of organic was vermicompost containing 1.8 per cent N on dry weight basis. Quality Protein Maize, variety 'HQPM-1' was grown as per the recommended agronomic practice (Pal and Bhatnagar, 2009). Nitrogen, phosphorus and potassium were applied as per the treatments through urea, SSP and MOP, respectively. Entire amount of vermicompost, full dose of P, K and Zinc as $ZnSO_4$ @ 25 kg ha^{1} and one third amount of N were applied as basal at the time of sowing, remaining N was given in two equal splits as top dressing at knee high and tassel emergence stages. After through preparation of field with one deep ploughing followed by two harrows, furrows were opened at 60 and 50 cm by furrow opener. Seeds were sown at a distance of 25 and 20 cm as per treatments. One pre-emergence spray of pendimethalin was made @ 3.33 l/ha in 500 litres of water one day after sowing followed by a manual weeding at 27 days after sowing (DAS) for an effective weed control. To control aphids and stem borers one spray of metasystox and endosulfan of 1:1 ratio was done @ 2ml/liter at 28 DAS, while to control heliothis (*Helicoverpa armigera*), profenophos was sprayed @ 3ml/liter at 41 DAS. The total nitrogen content was determined by the micro-Kjeldhal method, and the protein content in grain was estimated by multiplying per cent nitrogen in grain with factor 6.25 (AOAC, 1965). The tryptophan content (g/100g protein) was estimated by papain hydrolysis method as described by Hernandez and Bates (1969). The value of lysine was obtained by increasing the value of tryptophan by 4 times as per relationship observed by Hernandez and Bates (1969), between tryptophan and lysine in the maize endosperm protein.

Results and Discussion

Protein content was significantly altered with increase in plant density from 66,666 to 1,00,000 plants ha^{-1} and showed a declining trend. The maximum protein (11.01 %) was observed with 66,666 plants ha^{-1}, but statistically on par with that of 83,333 plants ha^{-1}. With increase in plant density, the N content in grains, an index of protein decreased significantly resulting in decreased protein content. The plants under high density might have faced competition for growth factors including nitrogen and thus, accumulated less nitrogen in grain. A negative relationship between grain yield and grain protein concentration has been reported in maize (Dudley *et al*., 1977). Decreasing trend for protein content with increasing plant population was also observed by Singh *et al*. (1997). Nutrient management practices consisting of variable

Table 1. Effect of plant density and nitrogen management on protein, lysine and tryptophan content and grain and protein yields of QPM

Treatments	N % in grain	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (t ha^{-1})	Protein yield (t ha^{-1})
Plant Density (Plants ha^{-1})						
66,666	1.76	11.01	3.15	0.79	5.767	0.635
83,333	1.72	10.77	3.13	0.78	6.549	0.706
100,000	1.68	10.50	3.10	0.78	6.990	0.734
SEm ±	0.02	0.10	0.07	0.02	0.195	0.023
CD (P = 0.05)	0.04	0.28	NS	NS	0.501	0.066
Mode of nutrition						
100 % RDF inorganic	1.72	10.74	3.10	0.77	6.458	0.693
125 % RDF inorganic	1.76	10.98	2.95	0.74	6.685	0.734
100% N inorganic + 25 % N organic	1.74	10.88	3.24	0.81	6.528	0.710
75% N inorganic + 25 % N organic	1.70	10.63	3.19	0.80	6.256	0.663
50% N inorganic + 50 % N organic	1.69	10.58	3.16	0.79	6.250	0.660
SEm ±	0.02	0.12	0.09	0.02	0.252	0.029
CD (P = 0.05)	NS	NS	NS	NS	NS	NS

proportion of organics and inorganics did not improve protein content significantly over the chemical fertilizers alone. Nitrogen management practices not showing a significant effect on N content in grain might be due to a proper supply of nitrogen in all the treatments, consequently, protein content remained statistically unaffected. However, treatments which received 25 per cent extra nitrogen *i.e*. 125 per cent RDF and 100 per cent N through inorganic + 25 per cent N through organic resulted in numerically more N per cent and consequently would have increased protein per cent in grain than rest of the treatments. These results are in agreement with with Malathesh (2005), who found non-significant effect of N substitution through organic on N content in maize.

Lysine and tryptophan contents in grain, which are the main quality aspects of QPM, were not influenced by plant density and mode of nutrition despite of a significant effect of plant density on the protein content. Tsai *et al*. (1983) also reported that lysine and tryptophan content in grain remained unaffected by variation in plant density. The increase in lysine and tryptophan contents in quality protein maize is triggered by *o2* gene, which partially inhibits zein synthesis, with proportional increase in other protein fractions. The extent of increase in lysine of *o2* mutants is highly influenced by the genetic background (Moro *et al.*, 1996). As the lysine and tryptophan contents are genetically controlled, plant density and nutrient management might have not been able to bring any significant effect. Vyn and Tollenar (1998) also observed non-significant effect of plant population on lysine and tryptophan concentration of grain.

Increase in plant density was found to increase the grain yield with 13.6 and 21.2 per cent at 83,333 and 1,00,000 plants ha^{-1}, respectively, over 66,666 plants ha^{-1}. However, the difference between 1,00,000 and 83,333 plants ha^{-1} remained non-significant. Increase in grain yield under higher plant density might be attributed to more number of plants per unit area and plant stand at harvest. The increase in grain yield with higher plant density has also been reported by Yogananda *et al.* (1999) and Sangoi (2000). Grain yield obtained in all the nitrogen management practices remained on par irrespective of inorganic or organic sources. It might be due to proper availability of nutrients in all the treatments. It suggests that selection of any mode of nutrition, whether chemical or in integration with organics depends on their availability. But by adopting integrated management practices, the beneficial effects of organics on soil health may be realized.

Protein yield, which is the product of grain protein and grain yield, was significantly affected with plant density with maximum value under 1,00,000 plants ha^{-1} (0.734 t ha^{-1}) that remained on par with that of 83,333 plants ha^{-1}. Since both the plant density 1,00,000 and 83,333 plants ha^{-1} were on par for protein content and grain yield , hence remained non significant each other for protein yield. Significantly lower protein yield in 66, 666 plants ha^{-1} might be attributed to the statistically poor protein content and grain yield under this treatment. These results corroborate the findings of Tokatlidis *et al*. (2005), who stated higher protein production per unit area at higher plant density in maize hybrids. As the nitrogen management practices did not show any significant effect on grain yield and protein content, protein yield remained unaltered.

Conclusion

The results of the present study indicate that more yield of quality protein maize 'HQPM 1' may be obtained at a density of 83,333 plants ha^{-1} without deteriorating protein quality and quantity. Chemical fertilizer dose may be replaced by organics to an extent of 25-50 per cent.

References

AOAC, 1965. Official methods of analysis. Association of official Agricultural Chemists. 10th ed. pp. 744-745.

Ahmadi, M., Wiebold, W.J., Beuerlein, J.E., Eckert, D.S. and Schoper, J. 1993. Agronomic practices that affect kernel characteristics. *Agron. J.*, **85**: 615-619.

Bjarnason, M. and Vasal, S.K. 1992. Breeding of quality protein maize (QPM). In: Plant breeding review, IAEA, Vienna, p:119.

Dudley, J.W., Lambert, R.J. and De La Roche,I.A. 1977. Genetic analysis of crosses among corn strains divergently selected for percent oil and protein. *Crop Sci*., **17**:111-117.

FAO, Agrostat 1992. Food balance sheets, FAO, Rome, Italy.

Glover, D.V. and Mertz, E.T. 1987. Corn. In: Nutritional quality of cereal grains: Genetic and agronomy improvement, Olson, R. A. and Frey, K.J. (Eds). American society of Agronomy, Madison, pp.183-336.

Hernandez, H.H. and Bates, L.S. 1969. A modified method for rapid tryptophan analysis in maize. CIMMYT Res. Bull. 13, International maize and Wheat improvement centre , Londres, Mexico.

Malathesh, G.H. 2005. Nutrient substitution through organics in maize. Thesis, M Sc. University of Agricultural Sciences, Dharwad, Karnataka, India.

McDermitt, D.K. and Loomis, R.S. 1981. Elemental composition of biomass and its relation to energy content, growth efficiency and yield. *Ann. Bot.*, **48**: 275–290.

Moro, G.L., Habben, J.E., Hamaker, B.R. and Larkins, B.A. 1996. Characterization of the variability in lysine content of normal and opaque 2 maize endosperm. *Crop Sci.*, **36**:1651-1659.

Neuberg, M., Pavlík, M., Balík, J., Kaliszova, R. and Pavlikova, D. 2010. The effect of ammonium nitrogen nutrition on the content of amino acids in red clover. *Agrochemica*, **24**: 9–12.

Pal, M.S. and Bhatnagar, A. 2009. Makka. In Pantnagar kissan diary. Directorate of extension education, GBPUA&T, Pantnagar, pp.20-23.

Pavlík, M., Pavlíkova, D., Staszkova, L., Neuberg, M., Kaliszova, R., Szakova, J. and Tlustos, P. 2010. The effect of arsenic con-tamination on amino acids metabolism in *Spinacia oleracea* L. *Ecotox. Environ. Safe.*, **73**: 1309–1313.

Prasanna, B.M., Vasal, S.K., Kassahun, B. and Singh, N.N. 2001. Quality protein maize. *Current Sci*., **81**(10):1311-1319.

Sander, D.H., Allaway, W.H. and Olson, R.A. 1987. Modification of nutritional quality by environment and production practices. In: Nutritional quality of cereal grains: Genetics and agronomic management, R.A. Olson and K.I. Frey (Eds), American society of Agronomy, Madison, pp. 45–82.

Sangoi, L. 2000. Understanding plant density effects on maize growth and development : an important issue to maximize grain yield. *Ciencia Rural*, **31**: 861-869.

Singh, A. K., Singh, G. R. and Dixit, R. S. 1997. Influence of plant population and moisture regimes on nutrient uptake and quality of winter maize (*Zea mays*). *Indian J. Agron.*, 42: 107-111.

Tokatlidis, I.S., Koutsika-Sotiriou, M. and Tamoutsidis, E. 2005. Benefits from usingmaize density-dependent hybrids. *Maydica*, **50**: 9-17.

Tsai, C. Y., Warren, H. L., Huber, D. M. and Bressan, R. A. 1983. Interactions between the kernel N sink, grain yield and protein nutritional quality of maize. *J. Sci. Food Agric*., **34**: 255-263.

Vyn, T.J. and Tollenaar, M. 1998. Changes in chemical and physical quality parameters of maize grain during three decades of yield improvement. *Field Crop Res*., **59**: 135-140.

Yogananda, S. B., Shivraj, B., Gowda, A. and Krishnamurthy, N. 1999. Effect of plant population, phosphorus and potassium levels on growth and yield of popcorn (*Zea mays* L.). *Mysore J. Agric. Sci*., **33**: 21-25.

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