Indian Journal of Agronomy **65** (1): 83–87 (March 2020)

Research Paper

Effect of integrated nutrient management on microclimatic environment, quality and yield of baby corn (*Zea mays*) in North-Western India

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Received: November 2018; Revised accepted: March 2020

ABSTRACT

A field experiment was conducted during the rainy season of 2013 and 2014 on sandy-loam soil of Ludhiana, Punjab, to study the effect of integrated nutrient management on yield and quality of baby corn (*Zea mays* L.). The maximum photosynthetically active radiation interception was recorded 60 days after sowing in plants receiving N-P-K @ 75-15-11.3 kg/ha through chemical fertilizer, which was statistically at par with 15 kg N/ha through FYM + 60 kg N/ha. The lowest soil and canopy temperature was recorded in N-P-K @ 75-15-11.3 kg/ha 30 days after sowing. The maximum baby corn yield was recorded in N-P-K @ 75-15-11.3 kg/ha which was statistically at par with 15 kg N/ha (FYM) + 60 kg N/ha and N-P-K @ 60-12-6 kg/ha. The protein content was significantly higher in plants received N-P-K @ 75-15-11.3 kg/ha, while sugar content was higher in plants received 30 kg N/ha through FYM + 30 kg N/ha through fertilizer than the other treatments. The starch, crude fibre, cob texture, total soluble solid and total solids were not significantly affected by both chemical and integrated nutrient management treatments.

Key words: Baby corn, Photosynthetically active radiation interception, Quality parameters.

Maize has been cultivated for centuries as a grain crop and more recently as a vegetable crop, such as baby corn and sweet maize (*Zea mays* var. saccharata). Maize is classified into different groups or types based on the endosperm of kernels among which baby corn is grown for vegetable purpose. Baby corn is dehusked maize ear, harvested young especially when the silk have either not emerged or just emerged and no fertilization has taken place or we can say the shank with unpollinated silk is baby corn. Baby corn ears light yellow in colour with regular row arrangement, 10 to 12 cm long and a diameter of 1.0 to 1.5 cm arrangement are preferred in the market (Golada *et al*., 2013).

As per the report of Early Intervention Research Institute, the nutritive value of baby corn on dry-weight basis is protein 15–18%, sugar: 0.016–0.020%, phosphorus: 0.6–0.9%, potassium 2–3%, fibre: 3–5%, calcium: 0.3–0.5% and ascorbic acid: 75–80 mg/100 g. In addition to high-nutritional value as human food, another benefit of baby corn consists of utilizing husk, silk and stover as green herbage for feeding ruminants and swine; only 13 to 20% of fresh ear weight is for human use. Baby corn cultivation being a relatively new practice in India, requires the development of suitable production technology in realizing higher baby corn yield and monetary returns before it could be popularized among maize growers. It is well established that the improvement of quality and productivity of crops could be made possible with combined application of organic manures and balanced chemical fertilizers. The concept of integrated nutrient management seeks to sustain soil fertility through an integration of different sources of nutrition that will produce the maximum crop yield/unit input use. The quality of the baby corn is very important for the higher economic value of the crop. The protein is formed by the nitrate assimilation in the plant as nitrogen is a constituent of protein. Keeping this in mind, an experiment was designed to study the productivity and quality of baby corn under irrigated ecosystem of North-Western India.

MATERIALS AND METHODS

An experiment was conducted during the rainy season of 2013 and 2014 at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (30°562N and 75°522E at 247 mean above sea-level). Ludhiana is located in the central plain region of Punjab in

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transgangetic plain agro-climatic zone of India. The area is under subtropical to semiarid climate with hot and dry summers (April–June), hot and humid monsoon periods (July–September), mild early winters (October–November) and cold winters from December to February. The mean minimum and maximum temperatures show considerable fluctuation during summer and winter. The mean maximum temperature was 36.6ºC and 40.6°C in June 2013 and 2014 respectively, and mean minimum temperature of 33.0ºC and 34.1ºC was recorded in August 2013 and 2014 respectively. Maximum air temperature above 38°C is common during summer and frequent frosts are experienced in December–January. The average annual rainfall lies between 658.7 and 273.8 mm; 75% is received in summer monsoon (July–September) complemented by a few showers in winter. Data recorded at the meteorological observatory of the Punjab Agricultural University, Ludhiana, during the crop-growing season indicated similar weather conditions during 2013 and 2014 crop-growth seasons. Total amount of rainfall received during the crop-growing seasons of 2013 and 2014 was 755.8 and 546.9 mm respectively. The mean monthly temperature ranged between 13.7–31.9 and 12.3–33.8 °C, whereas relative humidity remained 38.0–79.5 and 44.0–80.0% during 2013 and 2014 respectively. The reference evapotranspiration (ET) calculated with the calculator developed by FAO (http://www.fao.org/nr/water/eto.html) from the meteorological data of study years ranged from 2.9 to 10.2 mm/day in 2013 and from 2.5 to 10.3 mm/day in 2014.

The soil of the experimental site was slightly alkaline, sandy loam in texture, with low electrical conductivity (0.36 dS/m), organic carbon (0.29 %) and available nitrogen (185.2 kg/ha) and medium in available phosphorus (19.8 kg/ha) and available potassium (224.7 kg/ha). Available Zn, Mn, Fe and Cu (mg/kg) were in sufficient amount in the soil. The experiment was laid out in randomized complete-block design with 4 replications and 10 treatments, i.e. T_1, Control (unfertilized); T_2, recommended N (60 kg/ha); T_3, N-K_2O 60–6 kg/ha; T_4, N-P_2O_5 60–12; kg/ha; T_5, N-P_2O_5-K_2O 45–9–4.5; kg/ha; T_6, N-P_2O_5-K_2O 60-12-6 kg/ha; T_7, N-P_2O_5-K_2O 75–15–11.3 kg/ha; T_8, 30 kg N/ha (FYM) + 30 kg N/ha (through urea); T_9, 15 kg N/ha (FYM) + 45 kg N/ha (through urea); and T_{10}, 15 kg N/ha (FYM) + 60 kg N/ha (through Urea). The variety 'Composite Kesri' was sown with dibbling method at 30 cm × 20 cm spacing using 40 kg seed rate/ha in the last week of June 2013 and 2014. Nitrogen was given in the form of urea, phosphorus in the form of single superphosphate and potassium in muriate of potash. The N was applied in 2 splits irrespective of treatments. Half of N (as per treatment level) and full doses of P and K were applied at the time of sowing and full dose of organic manures was applied at the time of sowing as per treatment, and the remaining N was top-dressed 25 days after sowing. The crop was detasseled before pollen shed to prevent fertilization and also to divert nutrient flow to developing cob. Baby corns were dehusked manually and the yield of both baby corn and fodder was reported on a fresh-weight basis. The young baby corn ears were picked at the end of August 2013 and 2014 just at the silk-emergence stage and 5 pickings of baby corn were taken at an interval of 3–4 days. The tassel was removed as soon as it appears to check the pollination.

Line quantum sensor (LI-COR photometer Model LI-191-84) which measures quantum (photon) response through wavelength range of 400–700 nm for photosynthetic photon flux density (PPFD) was used for PAR measurement. Soil temperature (°C) was recorded from 5 cm soil depth with a bimetal soil thermometer between 9.00 AM and 10 AM and 2.00 PM and 3.00 PM for further use in reporting. The protein percentage in baby corn of each plot was worked out by multiplying its nitrogen content by 6.25. Nitrogen content in baby corn was estimated by modified Kjeldahl's distillation method. Texture measurement was done using texture analyser. The texture of baby corn was analysed from the horizontal middle portion of the baby corn. The total soluble solids (ºBrix) were determined using hand refractometer with range 0–32ºB (Erma, Tokyo) and readings were expressed ºB at 20ºC using reference tables. Total sugar content of baby corn cob was estimated by Nelson and Somogyi (1945) method with modification suggested by Asana and Saini (1962) and was expressed in percentage. The total solids were estimated by drying weighed sample (10–15 g) in the pre-weighed aluminium dish to a constant weight in a hot-air oven at 70ºC for 16–18 h. Crude fibre was determined by taking sample free from fat and moisture. Colorometric method was used for estimation of starch.

Analysis of variance was performed to determine the effect of integrated nutrient management on microclimatic environment, quality and yield of baby corn. The variance was analysed using Proc GLM (SAS software 9.1, SAS institute Ltd, USA) for both the years separately. The difference between means was compared with Fisher's least significant difference test (LSD) at 0.05 probability level.

RESULTS AND DISCUSSION

Microclimatic observations

Photosynthetically active radiation interception: The differences among light interception by various integrated nutrient management (INM) and chemical treatments were significant at 60 days after sowing, and all the INM treatments registered significantly more photosynthetically active radiation (PAR) interception than standard chemical fertilizer treatment (recommended N–60 kg/ha) (Table 1). The maximum PAR (30.5) was recorded in 15 kg N/ha (FYM) + 60 kg N/ha (through urea) and was statistically at par with N-P_2O_5-K_2O 75-15-11.3 kg/ha and N-P_2O_5-K_2O 60-12-6 kg/ha. The higher PAR interception may be due to more leaf-area index and closer spacing (30 cm × 20 cm) than standard maize crop (60 cm × 20 cm) in these treatments. Liu *et al*., (2016) reported higher interception (PARI) with highest row spacing.

Soil temperature: Soil temperature (°C) beneath the crop canopy presented in the Table 1 showed that, an increase in nutrient level tended to lower soil temperature. During both the cropping seasons, the lowest soil temperature (10.6°C) was recorded in N-P_2O_5-K_2O 75-15-11.3 kg/ha and the maximum (11.1°C) was under the control, which may be due to more leaf-area index and PARI (%) of these treatments as compared with the control plot.

Canopy temperature: The data for canopy temperature (°C) presented in Table 1 showed slightly higher values than that of soil temperature and showed similar trend as that of soil temperature. The minimum canopy temperature (9.9°C) was recorded in N-P_2O_5-K_2O 75-15-11.3 kg/ha and the maximum (10.9°C) in the control. The less temperature recorded in fertilized treatment may be owing to their more leaf area and more PARI (%). Similar results were reported by Singh *et al*. (2017).

Yield-attributing parameters

Chlorophyll content index: The chlorophyll content during both cropping seasons was the maximum in N-P-K 75-15-11.3 kg/ha which was statistically at par with 15 kg N/ha (FYM) + 60 kg N/ha and N-P_2O_5-K_2O 60-12-6 kg/ha might be owing to quick availability of applied fertilizes in these treatments and more labile N availability in the root rhizosphire (Table 1) and their uptake by plants (Table 1). Kumar (2009) reported similar advancement while studying the physiological basis of nitrogen-use efficiency in maize at various rates of applied nitrogen. Nitrogen supply has large effect on leaf growth because it increases the leaf area of plants and, on that way, its influences on photosynthesis.

Leaf-area index: A perusal of data on leaf-area index (Table 1) showed that leaf-area index (LAI) was maximum in N-P_2O_5-K_2O 75-15-11.3 kg/ha, which was statistically at par with N-P_2O_5-K_2O 60-12-6 kg/ha. The reduction in LAI may be because of environmental variation, i.e. due to temperature shift (rise in temperature) and drop in precipitation (little rainfall during 2014 cropping season). The N-P_2O_5-K_2O 75-15-11.3 kg/ha resulted in 9.4% reduction in LAI during 2014 when compared with 2013.

Dry matter accumulation: The dry-matter accumulation (DMA) is an indicator of solar energy harvested. The data pertaining to the DMA in Table 2 revealed that, the maximum DMA was recorded in N-P_2O_5-K_2O 75-15-11.3 kg/ha which was statistically at par with 15 kg N/ha (FYM) + 60 kg N/ha and the minimum DMA was observed in the control plot. The increased dry-matter production might be owing to better utilization of nutrients and phased release of nutrients as per requirement of maize. This corroborates the findings of Singh *et al*., (2017).

Number of cobs: The data pertaining to the number of cobs (Table 2) indicated that the number of cobs increased with the increase in nutrition level but the difference was not significant. The maximum number of cobs was recorded under N-P_2O_5-K_2O 75-15-11.3 kg/ha and the minimum under the control. Panwar and Munda (2006) also found the same trend for cobs/plant for nitrogen levels from 0 to 80 kg N/ha.

Harvest duration days: The harvest duration days depend on the green cob availability. Although the nutrition

Table 1. Effect of inorganic fertilizers and organic manure on photosynthetically active radiation (PARI) interception, soil temperature, canopy temperature, baby corn and green fodder yield of baby corn

Treatment	PARI (%)	Canopy temperature (°C)	Soil temperature (°C)	Leaf-area index	Chlorophyll content (SPAD value)
Control	20.8	10.9	11.1	0.69	8.5
Recommended N (60 kg/ha)	25.4	10.7	11.1	0.85	10.5
N-K_2O60-6 kg/ha	26.5	10.6	11.0	0.92	10.6
N-P 60–12 kg/ha	27.6	10.6	11.0	1.08	10.7
N-P_2O_5-K_2O 45-9-4.5 kg/ha	28.4	10.6	11.0	1.05	10.7
N-P_2O_5-K_2O 60-12-6 kg/ha	28.4	10.0	10.9	1.20	12,6
N-P_2O_5-K_2O 75-15-11.3 kg/ha	29.8	9.9	10.6	1.21	12.9
30 kg N/ha (FYM) + 30 kg N/ha	29.4	10.2	11.0	1.10	11.4
15 kg N/ha (FYM) + 45 kg N/ha	28.6	10.2	11.0	1.12	11.7
15 kg N/ha (FYM) + 60 kg N/ha	30.5	10.1	10.8	1.19	12.2
SEm±	0.58	0.07	0.36	0.003	0.23
CD (P=0.05)	1.76	0.21	0.10	0.01	0.70

had non-significant effect on harvest duration days in both years, as indicated by the data presented in Table 2. The treatment receiving recommended N (60 kg/ha) has numerically more harvest duration days than the control and arithmetically maximum number of harvest duration days was recorded in N-P-K 75-15-11.3 kg/ha. The reason could be that the number of cobs was increased as nutrition level increased which in turn enhanced the harvesting duration.

Marketable baby corn yield: The yield of baby corn was significantly affected by both inorganic and INM treatments. The maximum baby corn yield (0.51 t/ha) was recorded in N-P-K; 75-15-11.3; kg/ha which was statistically at par with 15 kg N/ha (FYM) + 60 kg N/ha (through urea) and N-P-K 60-12-6 kg/ha and per cent increase in the yield over recommended dose of fertilizer (N 60 kg/ha) was 27, 20.2 and 18.8 during experimental years which may be owing to more PARI and LAI. The integrated fertilization (30 kg N/ha (FYM) + 30 kg N/ha (through urea), 15 kg N/ha (FYM) + 45 kg N/ha (through urea) and 15 kg N/ha (FYM) + 60 kg N/ha (through urea) resulted in higher yield than the alone chemical fertilization (recommended N) (60 kg/ha), N-K 60-6 kg/ha, N-P 60-12 kg/ha and N-P-K 45-9-4.5 kg/ha might be due to synchronous availability of nutrients to the plant in the advancement of age through organic manure (FYM) in addition to supply of nitrogen from inorganic fertilizer (Table 2).

Similarly, maximum green fodder was recorded in N-P-K 75-15-11.3 kg/ha, being statistically at par with 15 kg N/ha (FYM) + 60 kg N/ha (through urea), N-P-K 60-12-6 kg/ha (8.60 t/ha) and the minimum green fodder yield was recorded in the control plots. The per cent increase in the green fodder yield over recommended dose of fertilizer (N 60 kg/ha) in N-P-K; 75-15-11.3; kg/ha, 15 kg N/ha (FYM) + 60 kg N/ha (through urea) and N-P-K 60-12-6 kg/ha treatments were 29.7, 24, 21.7 during experimental years. These findings are in agreement with those of Luikham *et*

Table 2. Effect of inorganic fertilizers and organic manure on protein content, sugar, starch, crude fibre, total solids, total soluble solids and cob texture in baby cob of baby corn

Treatment	Dry-matter accumulation (t/ha)	Cobs / plant	Harvest duration (days)	Baby corn dehusked yield (t/ha)	Green fodder yield (t/ha)
Control	1.159	0.60	33.3	0.264	5.203
Recommended N (60 kg/ha)	1.317	0.83	3.8	0.399	7.066
N-K 60-6 kg/ha	1.395	0.93	3.9	0.415	7.287
N-P 60-12 kg/ha	1.499	0.93	3.9	0.419	7.445
N-P-K 45-9-4.5 kg/ha	1.559	0.93	4.0	0.424	7.607
N-P-K 60-12-6 kg/ha	1.718	1.03	4.2	0.475	8.605
N-P-K 75-15-11.3 kg/ha	1.809	1.20	4.6	0.507	9.168
30 kg N/ha (FYM) + 30 kg N/ha	1.604	0.96	4.2	0.433	7.693
15 kg N/ha (FYM) + 45 kg N/ha	1.644	0.96	4.2	0.439	7.896
15 kg N/ha (FYM) + 60 kg N/ha	1.750	1.13	4.4	0.480	8.764
SEm±	0.25	0.112	0.319	0.011	0.39
CD (P=0.05)	0.76	NS	NS	0.032	1.17

Table 3. Effect of inorganic fertilizers and organic manure on protein content, sugar, starch, crude fibre, total solids, total soluble solids and cob texture in baby cob of baby corn

Treatment	Protein content (%)	Sugar (%)	Starch (%)	Crude fibre (%)	TSS (°B)	Total solids (%)
Control	3.65	2.3	0.79	0.70	2.93	4.97
Recommended N (60 kg/ha)	3.78	2.2	0.79	0.70	2.90	4.97
N-K (60-6) kg/ha	3.80	2.2	0.80	0.70	2.86	4.98
N-P (60-12) kg/ha	3.83	2.2	0.80	0.70	2.86	4.99
N-P-K (45-9-4.5) kg/ha	4.04	2.2	0.80	0.70	2.86	5.01
N-P-K (60-12-6) kg/ha	4.36	2.2	0.80	0.70	2.90	5.07
N-P-K (75-15-11.3) kg/ha	4.61	2.2	0.80	0.71	2.93	5.13
30 kg N/ha (FYM) + 30 kg N/ha	4.31	2.8	0.79	0.69	3.23	4.97
15 kg N/ha (FYM) + 45 kg N/ha	4.38	2.5	0.80	0.70	3.16	4.98
15 kg N/ha (FYM) + 60 kg N/ha	4.40	2.5	0.80	0.70	3.13	4.98
SEm±	0.01	0.155	0.022	0.018	0.113	0.113
CD (P=0.05)	0.05	NS	NS	NS	NS	NS

Table 4. Pearson correlation coefficient among yield and soil temperature and micro meteorological observations

	Pearson Correlation Coefficients, N = 10 Prob> |r| under H_0: Rh_o=0			
	PAR interception	Baby corn yield	Soil temperature	Canopy temperature
Baby corn yield	0.982**			
Soil temperature	-0.793**	-0.783**		
Canopy temperature	-0.830**	-0.775**	0.734**	
LAI	0.952**	0.922**	-0.770**	-0.886**

** = Significant at 1 and 5% level of significance
Not mentioned in text

al. (2006).

Quality parameters: The data in Table 3 showed that, with increment in the NPK level, the protein content varied from 3.65 % to 4.61% during experimental years. The maximum protein content and starch (0.80%) were observed under N-P_2O_5-K_2O 75-15-11.3 kg/ha, being significantly higher than all the other treatments. Our results support the findings of Bindhani *et al.* (2007). Application of FYM and higher levels of nitrogen resulted in higher chlorophyll and nitrogen content in plant which might be responsible for observed higher cob protein content. In addition to this, the maximum crude fibre and total solids were also observed in N-P_2O_5-K_2O 75-15-11.3 kg/ha, but the difference among the treatments for total solids and cob texture were non-significant. The crude fibre represents fibre percentage in baby cob, which is an important quality parameter for export purpose–lower the fibre percentage better the quality of baby corn. So, with increase in nutrition level the fibre content also increases, which deteriorates the quality of baby corn as presented in the Table 3. In contrast to this, the maximum sugar content and total soluble solids were recorded in 30 kg N/ha (FYM) + 30 kg N/ha (through urea), while the minimum sugar content was observed in all chemical fertilized treatments which may be due to the positive impact of organic manure (FYM). Baby corn yield was highly dependent on PAR interception and leaf-area index. Baby corn yield was significantly increased with the increase in PAR and leaf-area index. However, increase in soil temperature and canopy temperature because of more stress imposed on plant significantly decreased the baby corn yield (Table 2). Higher soil temperature resulted in higher value of canopy temperature. With the increase in leaf-area index there was significant increase in the PAR inception because leaves are the main part of plant responsible for PAR interception. With increase in soil and canopy temperature there was lower leaf-area index and PAR interception due to more stress imposed on plant. The protein content was significantly higher in N-P_2O_5-K_2O 75-15-11.3 kg/ha and sugar content was higher in 30 kg N/ha (FYM) + 30 kg N/ha than the other treatments. The starch, crude fibre, cob texture, total soluble solid and total solids were not significantly affected by both chemical and integrated nutrient-management treatments.

It may be concluded that application of N-P_2O_5-K_2O 75-15-11.3 kg/ha, 15 kg N/ha (FYM) + 60 kg N/ha and N-P_2O_5-K_2O (60-12-6) kg/ha significantly improved photosynthetically active radiation interception, reduced soil and canopy temperature and increased baby corn productivity over recommended N application (N 60 kg/ha) and INM treatments improved baby corn quality mainly protein content and sugar.

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