

Impact of moisture conservation and nutrient-management practices on performance of maize (*Zea mays*) in Tarai Region of West Bengal

BINOY CHHETRI¹ AND A.C. SINHA²

Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal 736 165

Received : December 2016; Revised accepted : January 2017

ABSTRACT

A field experiment was conducted during *Pre Kharif* seasons (February to May) of 2013 and 2014 at the Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal to evaluate the growth, yield and economics of maize (*Zea mays* L.) under moisture conservation and nutrient-management practices. Among the moisture-conservation practices, irrigation resulted in the highest yield attributes such as cob length, cob girth, 100-grain weight, cob/plant, grain/cob, rows/cob and grain weight/cob, leading to the highest grain yield (4.35 t/ha), stover yield (12.0 t/ha), harvest index (26.4%), water-use efficiency (0.11 kg/ha/mm), net returns (30.1 × 10³ ₹/ha) and benefit: cost ratio (1.19). Application of irrigation significantly increased the plant height (218 cm at harvesting), leaf-area index [4.41 at 75 days after sowing (DAS)], dry-matter accumulation (1,203 g/m² at harvesting), crop-growth rate (20.2 g/g/m² at 61–75 DAS), nitrogen (89.9 kg/ha), phosphorus (54.3 kg/ha) and potassium (104.1 kg/ha) uptake. Among the nutrient management practices, the highest plant height (216 cm at harvesting), leaf-area index (4.26 at 75 DAS), dry-matter accumulation (1,167 g/m² at harvest), crop-growth rate (19.5 g/g/m² at 61–75 DAS), grain yield (4.21 t/ha), stover yield (11.7 t/ha), harvest index (26.3%), nitrogen (90.3 kg/ha), phosphorus (51.5 kg/ha), potassium (99.4 kg/ha) uptake, net returns (25.8 × 10³ ₹/ha) and water-use efficiency (0.10 kg/ha-mm) were recorded under treatment receiving 75% recommended dose of fertilizer (RDF) + phosphate-solubilizing bacteria (PSB) + *Azotobacter* + vermicompost @ 5.0 t/ha but the highest benefit: cost ratio (0.98) was recorded under 100% RDF + PSB + *Azotobacter* (N₂). Our result showed that maize grown with irrigation and supplied with 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N₃) proved the best for obtaining overall gain on a sustainable basis.

Key words: Economics, Growth, Maize, Nutrient uptake, Yield attributes, Yield

Maize is a C₄ plant belonging to the grassy family Poaceae, with its origin in Central America. In West Bengal, maize is cultivated in an area of 128.7 thousand ha with a production of 522.4 thousand tonnes (IIMR, 2014). In North Bengal, pre-rainy season (*pre kharif*) maize are gaining popularity among the farmers primarily because of the optimum yield potential owing to residual supply of nutrients from previous crops. Unfortunately, inadequate supply of irrigation during *pre-kharif* season in this region is the major constraint for low grain yield. However, inadequate supply of water at its critical developmental stages and high sensitivity of different maize cultivars to water stress are of immense importance (Shakhatreh *et al.*, 2001). There is some evidence of decline in the productiv-

ity of *pre-kharif* maize even with the application of recommended dose of fertilizer. Moreover, the soils are deficient in nutrients, especially nitrogen, phosphorus and potassium. Limited rainfall during the February–May in these areas makes *pre-kharif* maize vulnerable to moisture-stress conditions during its critical growth stages, resulting in severe yield reduction. Thus, better management of moisture and nutrients is especially important for increasing crop production of maize in *tarai* region of West Bengal.

Relatively little is known about the response of *pre-kharif* maize to moisture-conservation and nutrient-management practices under *tarai* zone of West Bengal. The area therefore, requires adoption of location-specific soil-moisture conservation and nutrient-management practices by which the area could be enhanced on a production basis of maize. Hence this study was carried out to see the effect of moisture-conservation and nutrient-management practice on growth and yield of *pre-kharif* maize.

¹Corresponding author's Email: yonib2050@gmail.com

¹Field Assistant, Regional Research Station (HZ), Uttar Banga Krishi Viswavidyalaya, Kalimpong 734 301; ²Department of Agronomy, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar 736 165, West Bengal

MATERIALS AND METHOD

A field experiment was conducted during *pre-kharif* seasons (February to May) of 2013 and 2014 at the Instructional Farm, Pundibari, Coochbehar (26°19'86" N and 89°23'53" E, 43 m above mean sea-level), West Bengal. The climatic condition of *tarai* zone is sub-tropical, with eminent characteristics of rainfall, high humidity and prolonged winter. Physico-chemical properties of soil were: sand (64.19%), silt (20.47%) and clay (15.34%) measured by inter-national pipette method (Piper, 1950). The soil had pH 5.11 measured by potentiometric method (Jackson, 1967), organic carbon (0.85%) measured by tritrimetric determination (Walkley and Black, 1934), total nitrogen (211.5%) measured by modified Kjeldahl's method (Jackson, 1967), available phosphorous (18.24 kg/ha) measured by Bray's method (Jackson, 1967) and available potassium (112.93 kg/ha) measured by flame photometer method (Jackson, 1967). Four types of moisture-conservation practices such as M_0 , without irrigation and without mulch; M_1 , irrigation as and when required (2 irrigations at knee-high and silking stage); M_2 , dry weed biomass mulch @ 5.0 t/ha; M_3 , FYM mulch @ 5.0 t/ha, were assigned to main plots. Different sources of nutrients were used to assign 4 different subplot treatments such as N_1 , 100% recommended dose of fertilizer (RDF); (80 kg/ha N + 40 kg/ha P + 40 kg/ha K); N_2 , 100% RDF + phosphate-solubilising bacteria (PSB) + *Azotobacter*; N_3 , 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha; N_4 , 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha. The experiment was laid out in a split-plot design with 3 replications. The results were analyzed taking consideration of pre-harvest parameters such as plant height, dry-matter accumulation (DMA g/m²), leaf-area index (LAI) (Watson, 1947) and crop-growth rate (CGR g/g/m²) (Watson, 1952), water-use efficiency (WUE) (Reddy and Reddi, 2007) whereas post-harvest parameters such as cobs/plant, grain/cob, 100-grain weight (g), cob length (cm), cob girth (cm), grain yield (t/ha), stover yield (t/ha), harvest index (%), nitrogen, phosphorus and potassium uptake (kg/ha). Economic analysis is total cost of cultivation (₹/ha), gross income (₹/ha), net income (₹/ha) and benefit: cost ratio. The pooled data obtained from 2 years (2013 and 2014) studies were analyzed statistically following split-plot design as per the procedure given by Gomez and Gomez (1984).

RESULT AND DISCUSSION

Growth parameters

The plant height of maize gradually increased with the advancement of crop age. However, there was an increasing trend of plant height up to harvesting. Higher plant height (218 cm at harvest) was observed under irrigated

plot (M_1) and this might be owing to easy availability of soil moisture which helps to develop suitable environment for root growth and improve micro-environment for their growth (Table 1). Maize plant height increases on application of irrigation at critical stages (Girijesh *et al.*, 2014). The highest dry-matter (1203 g/m² at harvest) accumulation, leaf-area index (4.41 at 75 DAS) and crop-growth rate (20.2 g/m² at 61–75 DAS) was also recorded under irrigated plot (Table 1). De and Bandyopadhyay (2013) reported higher values of growth parameters such as dry-matter accumulation, LAI and CGR in irrigated plots and application of irrigation along with mulch significantly increased the leaf-area index of spring maize (Singh *et al.*, 2015). Moisture-conservation practices by FYM and dry weed biomass mulch significantly influenced the growth parameters of maize. The highest plant height (211 cm at harvest) LAI, (4.21 at 75 DAS), DMA (1132 g/m² at harvesting) and CGR (18.68/g/m²) at 61–75 DAS) was recorded under FYM mulch compared to dry weed biomass mulch (Table 1). The lowest growth parameters were recorded under without irrigation and mulch (M_0). Spreading of FYM as mulching materials increased the moisture content in soil which enhanced the crop growth and development (Singh *et al.*, 2014). This might be owing to mulch

Table 1. Effect of moisture conservation and nutrient management practices on growth parameters of maize (2 years pooled data)

| Treatment | Plant height (cm) (At harvesting) | Leaf-area index (At 75 DAS) | Dry-matter accumulation (g/m ²) (At harvesting) | Crop-growth rate (g/g/m ²) (At 61–75 DAS) |
|--|-----------------------------------|-----------------------------|---|---|
| <i>Moisture-conservation practices (M)</i> | | | | |
| M_0 | 192 | 3.92 | 953 | 15.4 |
| M_1 | 218 | 4.41 | 1,203 | 20.2 |
| M_2 | 206 | 4.10 | 1,082 | 17.2 |
| M_3 | 211 | 4.21 | 1,132 | 18.6 |
| SEm± | 1.31 | 0.01 | 5.20 | 0.33 |
| CD (P=0.05) | 4.51 | 0.05 | 17.9 | 1.12 |
| <i>Nutrient management Practices (N)</i> | | | | |
| N_1 | 204 | 4.13 | 1,069 | 17.1 |
| N_2 | 209 | 4.19 | 1,112 | 18.2 |
| N_3 | 216 | 4.26 | 1,167 | 19.5 |
| N_4 | 197 | 4.06 | 1,023 | 16.5 |
| SEm± | 1.29 | 0.02 | 2.42 | 0.11 |
| CD (P=0.05) | 3.77 | 0.04 | 7.07 | 0.33 |

M_0 , without irrigation and without mulch; M_1 , irrigation as and when required; M_2 , dry-weed biomass mulch @ 5.0 t/ha; M_3 , FYM mulch @ 5.0 t/ha; N_1 , 100% RDF 80:40:40 kg/ha N: P₂O₅: K₂O; N_2 , 100% RDF + Phosphate solubilising bacteria (PSB) + *Azotobacter*; N_3 , 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha; N_4 , 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha

particularly restricts the loss of water vapour from soil surface to microclimate and diminishes the direct evaporation loss of water (Yaun *et al.*, 2009) and increased the availability of soil water to the crops that enhances the growth and development of crops (Fuchs and Hadas, 2011). The higher plant height, (216 cm at harvest), leaf-area index, (4.26 at 75 DAS) dry-matter accumulation (1167 g/m² at harvest) and crop growth rate (19.5 g/g/m² at 61–75 DAS) were recorded under 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N₃) compared to the other treatments (Table 1). This might be owing to the availability and absorption of higher amount of macro- and micro- nutrients from the applied nutrients in soil like vermicompost, inorganic fertilizers, phosphate-solubilising bacteria and *Azotobacter*. The application of vermicompost and 100% recommended dose of fertilizer significantly influenced the growth of maize (Hebbarai *et al.*, 2006).

Yield-attributing characters and yield of maize

The moisture-conservation practices significantly influenced the yield-attributing characters and yield of maize. However, the highest cob/plant (1.49), grain/cob (338), 100-grain weight (35.1 g), cob length (18.5 cm), cob girth (15.8 cm), rows/cob (17.1) and grain weight/cob (81.9 g) was recorded under irrigated plot (M₁) compared to the other treatments (Table 2). Elzubeir and Mohamed (2011) also found the highest values of yield-attributing parameters like cob girth, cob length on application of 2 irrigations at silking and grain-development stage. Application

of 2 irrigations at knee-high and silking stage recorded the highest grain yield (4.35 t/ha), stover yield (12.0 t/ha) and harvest index (26.4%) (Table 3). This might be owing to the improved moisture content in soil which enhanced the crop growth, yield-attributing characters and ultimately increased the yield. Moisture-conservation practices by FYM and dry-weed biomass mulch also significantly influenced the yield attributing characters such as rows/cob, 100-grain weight, grain/cob, cob length, cob girth, rows/cob, grain weight/cob, grain yield, stover yield and harvest index (Tables 2, 3). The moisture conservation practices by mulching significantly influenced the yield attributes and yield of maize as reported by Kumar (2015).

The use of nutrients in an integrated manner significantly increased the yield-attributing characters and yield. The highest cob/plant (1.47), grain/cob (319), 100-grain weight (34.6 g), cob length (18.7 cm), cob girth (16.0 cm), rows/cob (17.1), grain weight/cob (79.8 g) and grain yield (4.2 t/ha), stover yield (11.7 t/ha) and harvest index (26.3%) were found with treatments receiving 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N₃) (Tables 2, 3). Increase in grain and stover yields with integration of inorganic fertilizers along with vermicompost, *Azotobacter* and phosphate-solubilizing bacteria might be owing to improved yield-attributing characters (rows/cob, grain/row, 100-grain weight, grain/cob, cob length, rows/cob, grain weight and cob girth). The use of nutrients in an integrated manner significantly influenced the yield-attributing characters and grain yield of maize (Hashim *et al.*, 2015).

Table 2. Effect of moisture conservation and nutrient-management practices on yield attributes of maize (2 years pooled data)

| Treatment | Cobs/plant | Grain/cob | 100-grain weight (g) | Cob length (cm) | Cob girth (cm) | Rows/cob | Grain weight/cob |
|--|------------|-----------|----------------------|-----------------|----------------|----------|------------------|
| <i>Moisture Conservation Practices (M)</i> | | | | | | | |
| M ₀ | 1.22 | 238 | 28.6 | 14.3 | 13.3 | 13.1 | 68.0 |
| M ₁ | 1.49 | 338 | 35.1 | 18.5 | 15.8 | 17.1 | 81.1 |
| M ₂ | 1.33 | 313 | 31.2 | 15.7 | 14.4 | 14.9 | 75.7 |
| M ₃ | 1.40 | 322 | 32.1 | 16.7 | 14.9 | 15.9 | 77.7 |
| SEm± | 0.04 | 9.77 | 0.86 | 0.59 | 0.22 | 0.51 | 1.40 |
| CD (P=0.05) | 0.12 | 33.81 | 2.98 | 2.01 | 0.76 | 1.57 | 4.78 |
| <i>Nutrient Management Practices (N)</i> | | | | | | | |
| N ₁ | 1.33 | 298 | 30.7 | 15.4 | 14.1 | 14.6 | 75.2 |
| N ₂ | 1.39 | 307 | 32.4 | 16.8 | 15.0 | 15.7 | 77.1 |
| N ₃ | 1.47 | 319 | 34.6 | 18.7 | 16.0 | 17.1 | 79.8 |
| N ₄ | 1.25 | 286 | 29.4 | 14.3 | 13.3 | 13.5 | 71.5 |
| SEm± | 0.02 | 5.54 | 0.82 | 0.48 | 0.45 | 0.36 | 0.97 |
| CD (P=0.05) | 0.07 | 16.17 | 2.41 | 1.41 | NS | 1.25 | 3.34 |

M₀, without irrigation and without mulch; M₁, irrigation as and when required; M₂, dry-weed biomass mulch @ 5.0 t/ha; M₃, FYM mulch @ 5.0 t/ha; N₁, 100% RDF 80:40:40 kg/ha N: P₂O₅: K₂O; N₂, 100% RDF + Phosphate solubilising bacteria (PSB) + *Azotobacter*; N₃, 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha; N₄, 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha

Nutrient uptake of maize

The highest uptake of nitrogen (89.9 kg/ha), phosphorus (54.3 kg/ha) and potassium (1104.9 kg/ha) was recorded under irrigated plot (M_1) (Table 3). This might be because of adequate supply of moisture that influenced the nutrient uptake of N, P and K as reported by Mudalagiriappa *et al.* (2012). The moisture-conservation practices by FYM mulch also resulting in the highest uptake of nitrogen (84.9 kg/ha), phosphorus (49.9 kg/ha) and potassium (96.7 kg/ha) compared to the dry-weed biomass mulch (Table 3). Application of FYM as a mulch material not only efficiently conserved the soil moisture but also provided the better availability of nutrients, improved the soil physical properties (Chander *et al.*, 2013) and increases the nutrient uptake by maize (Kumar, 2015).

The nutrient-management practices significantly influenced the uptake of nitrogen, phosphorus and potassium in maize might be owing to the higher biomass and grain yield, as uptake is the resultant of higher dry-matter content and percentage of nutrients content in crop (Table 3). However, the highest uptake of nitrogen (90.3 kg/ha), phosphorus (51.5 kg/ha) and potassium (99.4 kg/ha) was recorded under treatments receiving 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3) (Table 3). This might be owing to the increased growth, nutrient influx and photosynthetic rate which resulted in more absorption and translocation of these nutrients to the grain and stover. Moreover, balanced and integrated nutrient-management practices significantly influenced the higher uptake of primary nutrients (Owla *et al.*, 2015).

Economics

The effect of moisture conservation practices, highest gross return (55.3×10^3 ₹/ha), net returns (30.1×10^3 ₹/ha) and benefit: cost ratio (1.19) were recorded under irrigated plot (M_1) (Table 4). The higher profitability of this treatment might be owing to the higher grain yield and lower total cost of cultivation and better utilization of moisture which improved the fertility of soil which ultimately increased the yield. The moisture-conservation practices by mulching, FYM mulch resulted in the highest gross return (48.9×10^3 ₹/ha) net return (23.7×10^3 ₹/ha) and benefit: cost ratio (0.95) compared to the dry-weed biomass mulch. However, the lowest gross return (34.5×10^3 ₹/ha), net return (9.3×10^3 ₹/ha) and benefit: cost ratio (0.37) were recorded under without irrigation and mulch (M_0). This might be that to the fact FYM and dry-weed biomass mulch significantly increases the availability of moisture to the crops which ultimately increased the net return and benefit: cost ratio. Moreover, use of straw as mulch material significantly increases the higher net returns and benefit: cost ratio over spreading FYM mulch and no mulching as reported by Singh *et al.*, (2014).

The highest gross return (53.3×10^3 ₹/ha) and net return (25.8×10^3 ₹/ha) were obtained under treatments receiving 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N_3), owing to the higher grain yield (Table 4). However, the highest benefit: cost ratio (0.98) was recorded under treatment receiving 100% RDF and *Azotobacter* + PSB (N_2) because of the lower cost of cultivation compared to the other treatments (Table 4). The application of

Table 3. Effect of moisture conservation and nutrient management practices on yield and NPK uptake of maize (2 years pooled data)

| Treatment | Grain yield (t/ha) | Stover yield (t/ha) | Harvest index (%) | Nitrogen (kg/ha) | Phosphorus (kg/ha) | Potassium (kg/ha) |
|--|--------------------|---------------------|-------------------|------------------|--------------------|-------------------|
| <i>Moisture Conservation Practices (M)</i> | | | | | | |
| M_0 | 2.73 | 9.53 | 22.1 | 76.4 | 41.4 | 85.5 |
| M_1 | 4.35 | 12.0 | 26.4 | 89.9 | 54.3 | 104.1 |
| M_2 | 3.29 | 10.8 | 23.2 | 81.4 | 44.7 | 91.1 |
| M_3 | 3.85 | 11.3 | 25.3 | 84.9 | 49.9 | 96.7 |
| SEm± | 0.86 | 0.52 | 0.53 | 1.00 | 0.82 | 0.96 |
| CD (P=0.05) | 2.96 | 1.83 | 1.85 | 3.00 | 2.42 | 2.99 |
| <i>Nutrient Management Practices (N)</i> | | | | | | |
| N_1 | 3.36 | 10.7 | 23.8 | 80.7 | 46.5 | 92.7 |
| N_2 | 3.69 | 11.1 | 24.7 | 85.8 | 48.6 | 95.8 |
| N_3 | 4.21 | 11.7 | 26.3 | 90.3 | 51.5 | 99.4 |
| N_4 | 2.96 | 10.2 | 22.2 | 76.1 | 43.8 | 89.6 |
| SEm± | 0.46 | 0.24 | 0.25 | 0.36 | 0.53 | 0.50 |
| CD (P=0.05) | 1.35 | 0.72 | 0.74 | 1.24 | 1.83 | 1.74 |

M_0 , without irrigation and without mulch; M_1 , irrigation as and when required; M_2 , dry-weed biomass mulch @ 5.0 t/ha; M_3 , FYM mulch @ 5.0 t/ha; N_1 , 100% RDF 80:40:40 kg/ha N: P_2O_5 : K_2O ; N_2 , 100% RDF + Phosphate solubilising bacteria (PSB) + *Azotobacter*; N_3 , 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha; N_4 , 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha

Table 4. Effect of moisture conservation and nutrient management practices on economics and water-use efficiency of maize cultivation (2 years pooled data)

| Treatment | Cultivation cost ($\times 10^3$ /ha) | Gross return ($\times 10^3$ /ha) | Net return ($\times 10^3$ /ha) | Benefit: cost ratio | Water-use efficiency (Kg/ha-mm) |
|--|---------------------------------------|-----------------------------------|---------------------------------|---------------------|---------------------------------|
| <i>Moisture Conservation Practices (M)</i> | | | | | |
| M ₀ | 23.7 | 34.5 | 9.3 | 0.37 | 0.06 |
| M ₁ | 23.7 | 55.3 | 30.1 | 1.19 | 0.11 |
| M ₂ | 24.5 | 41.6 | 16.4 | 0.65 | 0.08 |
| M ₃ | 24.7 | 48.9 | 23.7 | 0.95 | 0.09 |
| SEm± | - | 1080.2 | 1075.3 | 0.04 | 0.002 |
| CD (P=0.05) | - | 3,729.4 | 3,702.1 | 0.14 | 0.006 |
| <i>Nutrient Management Practices (N)</i> | | | | | |
| N ₁ | 23.7 | 42.6 | 18.9 | 0.80 | 0.08 |
| N ₂ | 23.7 | 46.8 | 23.1 | 0.98 | 0.09 |
| N ₃ | 27.5 | 53.3 | 25.8 | 0.93 | 0.10 |
| N ₄ | 25.9 | 37.5 | 11.6 | 0.45 | 0.07 |
| SEm± | - | 620.1 | 612.4 | 0.02 | 0.001 |
| CD (P=0.05) | - | 1,810.3 | 1,805.2 | 0.07 | 0.004 |

M₀, without irrigation and without mulch; M₁, irrigation as and when required; M₂, dry-weed biomass mulch @ 5.0 t/ha; M₃, FYM mulch @ 5.0 t/ha; N₁, 100% RDF 80:40:40 kg/ha N: P₂O₅: K₂O; N₂, 100% RDF + Phosphate solubilising bacteria (PSB) + *Azotobacter*; N₃, 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha; N₄, 50% RDF + PSB + *Azotobacter* + 50% vermicompost @ 2.5 t/ha

vermicompost and increased recommended dose of fertilizers from 50 to 100% enhanced the yield, but net return and benefit: cost ratio were lower due to the high cost of cultivation, as also reported by Nagappa and Biradar (2007). However, application of recommended dose of fertilizers along with *Azotobacter* resulted in higher net returns and benefit: ratio as also reported by Joshi *et al.*, (2013).

Water-use efficiency

The water-use efficiency was highest (0.11 kg/ha/mm) under treatment supplied with 2 irrigations– at knee-high and silking stage. The moisture conservation practices involving FYM mulch exhibited the highest-water use efficiency as compared to dry weeds biomass mulch (Table 4). Mulching significantly influenced the water-use efficiency of maize, might be owing to the reduction of evaporation loss through organic mulch was responsible for higher water-use efficiency by the crop (Sarkar and Singh, 2007). Among the nutrient-management practices, the highest (10.10 kg/ha/mm) water-use efficiency was recorded under treatments receiving 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N₃) compared to the other treatments. This might be owing to the availability of applied nutrients was attributable to higher grain production per unit of water used with better utilization of nutrient, water, improved root growth and higher nutrient uptake.

Application of 2 irrigations at knee-high and silking

stage significantly affects the growth, productivity and profitability of maize. Adoption of moisture-conservation practices by applying FYM and dry weed biomass mulch helped in improving the crop growth and yields in a sustainable way. The use of different sources of nutrient not only increased the availability of nutrients but also their uptake by the crop and proved to be better in terms of growth and yield of the maize. From this study, it is recommended to apply 75% RDF + PSB + *Azotobacter* + vermicompost @ 5.0 t/ha (N₃) along with 2 irrigations at knee-high stage and silking stage of maize for obtaining overall gain under the *tarai* region of West Bengal.

REFERENCES

- IIMR, 2014. Director's Review 2014–15. Indian Institute of Maize Research, New Delhi.
- Chander, G., Suhas, P., Wani, K. Sahrawat, L., Pal, C.K. and Mathur, T.P. 2013. Integrated plant genetic and balanced nutrient management enhances crop and water productivity of rainfed production systems in Rajasthan, India. *Communications in Soil Science and Plant Analysis* **44**(22): 3,456–3,464.
- De, B. and Bandyopadhyay, S. 2013. Influence of soil conservation techniques on growth and yield of maize (*Zea mays* L.) in Terai region of West Bengal. *SAARC Journal of Agriculture* **11**(1): 133–147.
- Elzubeir, A.O. and Mohamed, A.E. 2011. Response of maize (*Zea mays* L.) growth and yield to irrigation regimes and different tillage systems in arid area of Sudan. *Agricultural and Biological Journal of North America* **2**(6): 1,015–1,021.
- Fuchs, M. and Hadas, A. 2011. Mulch resistant to water vapour transport. *Agriculture Water Management* **98**(6): 990–998.

- Girijesh, G.K., Kumara Swamy, A.S., Kumar, D.M., Nataraju, S.P., Vageesh, T.S. and Rajashekarappa, K.S. 2014. Response of maize (*Zea mays* L.) to constraint irrigation under late sown conditions. *Karnataka Journal Agricultural Sciences* **24**(5): 633–635.
- Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*, edn 2, An International Rice Research Institute Book. Wiley-Inter-Science Publication, John Wiley & Sons, New York.
- Hashim, M., Dhar, Shiva, Vyas, A.K., Pramesh, V. and Kumar, B. 2015. Integrated nutrient management in maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **60**(3): 352–359.
- Hebbarai, M., Ganiger, V.M., Reddy, B.G.M. and Joshi, V.R. 2006. Integrated nutrient management sapota (*Manilkara zapota*) using vermicompost to increase yield and quality. *Indian Journal of Agricultural Sciences* **76**(10): 587–590.
- Jackson, M.L. 1967. *Soil Chemical Analysis*. pp. 183–408. Prentice Hall of India Pvt. Ltd., New Delhi.
- Joshi, E., Nepalia, V., Verma, A. and Singh, D. 2013. Effect of integrated nutrient management on growth, productivity and economics of maize (*Zea mays* L.). *Indian Journal of Agronomy* **58**(3): 434–436.
- Kumar, R. 2015. Productivity, profitability and nutrient uptake of maize (*Zea mays* L.) as influenced by management practices in North-East India. *Indian Journal of Agronomy* **60**(2): 273–278.
- Mudalagiryappa, B.K., Ramachandrappa, H.V. and Nanjappa, T. 2012. Moisture conservation practices and nutrient management on growth and yield of *rabi* sorghum (*Sorghum bicolor*) in the Vertisols of peninsular India. *Agricultural Sciences* **3**(4): 588–593.
- Nagappa, C.A.S. and Biradar, D.P. 2007. Effect of integrated nutrient management on productivity, profitability and sustainability of irrigated maize. *Karnataka Journal Agricultural Sciences* **20**(4): 837–839.
- Owla, M.L., Nepalia, V., Chouhan, G.S. and Singh, D. 2015. Effect of fertility levels, nutrient sources and weed control on weed dynamics and yield of quality protein maize (*Zea mays* L.) and relative nitrogen and phosphorus uptake. *Indian Journal of Agronomy* **60**(2): 267–272.
- Piper, C. S. 1950. *Soil and Plant Analysis*. Academic Press, New York.
- Reddy, T.Y. and Reddi, G.H.S. 2007. *Principles of Agronomy*. **3**: 286–289. Kalyani Publishers.
- Sarkar, S. and Singh, S.R. 2007. Interactive effect of tillage depth and mulch on soil temperature, productivity and water use pattern of rainfed barley (*Hordeum vulgare* L.). *Soil and Tillage Research* **92**(1/2): 79–86.
- Shakhatareh, Y., Kafawin, O., Ceccarelli, S. and Saoub, H. 2001. Selection of barley lines for drought tolerance in low-rainfall areas. *Journal of Agronomy and Crop Science* **186**: 119–127.
- Singh, K.B., Jalota, S.K. and Gupta, R.K. 2015. Soil water balance and response of spring maize (*Zea mays* L.) to mulching and differential irrigation in Punjab. *Indian Journal of Agronomy* **60**(2): 279–284.
- Singh, R.K., Singh, A. and Singh, K. 2014. Effect of moisture conservation practices on linseed (*Linum usitatissimum* L.) under ranfed conditions. *Environment and Ecology* **32**(2): 425–427.
- Walkley, A. and Black, I. A. 1934. An Examination of the Degtjareff method for determining Soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **34**: 29–38.
- Watson, D.J. 1947. Comparative physiological studies on the growth of field crops. *Annals of Botany* **11**: 41–76.
- Watson, D.J. 1952. The Physiological basis of Variation in Yield. *Advances in Agronomy*. **4** : 104–145.
- Yuan, C., Lei, T., Mao, L., Liu, H. and Wu, Y. 2009. Soil surface evaporation processes under mulches of different sized gravel. *Catena* **78**: 117–121.