

## Weed dynamics, productivity and economics of quality protein maize (*Zea mays*) as affected by weed and nutrient-management

VERSHA GUPTA<sup>1</sup>, ARVIND VERMA<sup>2</sup>, JAI PRAKASH BHIMWAL<sup>3</sup>, V. NEPALIA<sup>4</sup> AND H.K. JAIN<sup>5</sup>

Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313 001

Received: December 2021; Revised accepted: April 2023

### ABSTRACT

A field experiment was conducted during 2015–16 and 2016–17 at Instructional Farm (Agronomy), Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, to evaluate the effect of weed and nutrient-management on quality protein maize. The experiment consisting of 9 weed-management treatments, viz. weedy check, hand-weeding at 15 days after sowing (DAS) and 35 DAS, tembotrione 0.125 kg/ha at 20 DAS, alachlor 2 kg/ha as pre-emergence (PE) followed by (*fb*) hand-weeding at 35 DAS, atrazine 0.5 kg/ha as PE *fb* hand-weeding at 35 DAS, tembotrione 0.125 kg/ha at 20 DAS *fb* hand-weeding at 35 DAS, alachlor 2 kg/ha + atrazine 0.5 kg/ha as PE *fb* hand-weeding at 35 DAS, alachlor 2 kg/ha as PE *fb* tembotrione 0.125 kg/ha at 20 DAS and atrazine 0.5 kg/ha as PE *fb* tembotrione 0.125 kg/ha at 20 DAS with 3 nutrient-management treatments, viz. NPK, NPK + Zn and NPKS + Zn, were replicated thrice in a split-plot design. The maximum reduction of weed density (8.35) and dry-matter (133.6 g) was recorded with atrazine 0.5 kg/ha *fb* tembotrione 0.125 kg/ha. Atrazine 0.5 kg/ha *fb* tembotrione 0.125 kg/ha resulted in maximum number of grains/cob (367.91), grain weight (82.79 g), 1,000-seed weight (212.03 g) and shelling % (76.58) and ensued significantly higher grain (4.5 t/ha) and stover (7.5 t/ha) yields. Application of NPKS + Zn showed significantly higher yield attributes as well as grain (4.3 t/ha) and stover (7.2 t/ha) yield.

**Key words:** Atrazine, Alachlor, Nutrient management, Quality protein maize, Tembotrione, Weed management

Maize (*Zea mays* L.) is one of the major cereal crops with wide adaptability to different agro-climatic and edaphic conditions. In this crop, the content of essential amino acids, viz. lysine and tryptophan, are low, while leucine and isoleucine contents are high (Jat *et al.*, 2013). Weed is one of the most important yield limiting factors in rainy (*kharif*) season maize and significantly reduces the yield by 28–100% (Dass *et al.*, 2012). Atrazine and alachlor have been widely recommended for effective control of weeds in maize (Tahir *et al.*, 2011). Atrazine is however not effective against sedges like *Cyperus rotundus* L. (Singh *et al.*, 2015). Hence, there is need for some alternate post-emergence herbicide like tembotrione which can pro-

Based on a part of Ph.D. Thesis of the first author submitted to Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan in 2018 (unpublished)

<sup>1</sup>Corresponding author's Email: guptavershakota@gmail.com

<sup>1,3</sup>Ph.D. Scholar, <sup>2</sup>Professor, <sup>4</sup>Professor and Head, Department of Agronomy; <sup>5</sup>Professor, Department of Statistics, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313 001

vide broad-spectrum weed control in *kharif* maize without affecting the crop growth and yield of crop (Singh *et al.*, 2012). Nutrient-management plays a key role in sustaining the productivity of maize. Quality protein maize (QPM) is high nutrient-requiring crop and responds well to higher levels of chemical fertilizers. Thus, higher yield of QPM can be obtained through the judicious and higher uses of 2 major nutrients (N and P), as these 2 nutrients alone contribute 40–60% of the crop yield (Das *et al.*, 2010). Among the secondary and micronutrients, S and Zn have also a specific vital role in growth and development of crops (Duraisami *et al.*, 2007). Lots of applied nutrients in maize are taken away by the weeds, reducing the nutrient-use efficiency. The extent of nutrient loss by weeds varies from 30 to 40% of the applied nutrients (Mundra *et al.*, 2002). By appropriate weed management, the efficiency of applied nutrients can be increased and productivity and profitability can be improved. Hence a study was carried out to evaluate the effect of weed and nutrient-management on weed dynamics, productivity and economics of quality protein maize.

## MATERIALS AND METHODS

A field experiment was conducted during 2015–16 and 2016–17 at Instructional Farm (Agronomy), Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (74°42' E, 24°35' N, 579.5 m above mean sea-level) Rajasthan. The region falls under agro-climatic zone IVa (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan. This zone possesses a typical subtropical climatic condition, characterized by mild winters and moderate summers associated with high relative humidity. The mean annual rainfall of the region is 637 mm. Soil of experimental site was clay loam, slightly alkaline (pH 8.1 and 8.0) and medium in available nitrogen (285.0 and 279.6 kg/ha) and phosphorus (20.4 and 19.2 kg/ha) and high in available potassium (324.1 and 318.1 kg/ha) and low in available sulphur (9.7 and 9.3 kg/ha) during both 2015–16 and 2016–17 respectively. The experiment consisted of 9 weed-management treatments, viz. weedy check, hand-weeding at 15 days after sowing (DAS) and 35 DAS, tembotrione 0.125 kg/ha at 20 DAS, alachlor 2 kg/ha as pre-emergence (PE) followed by (*fb*) hand-weeding at 35 DAS, atrazine 0.5 kg/ha as PE *fb* hand-weeding at 35 DAS, tembotrione 0.125 kg/ha at 20 DAS *fb* hand-weeding at 35 DAS, alachlor 2 kg/ha + atrazine 0.5 kg/ha as PE *fb* hand-weeding at 35 DAS, alachlor 2 kg/ha as PE *fb* tembotrione 0.125 kg/ha at 20 DAS and atrazine 0.5 kg/ha as PE *fb* tembotrione 0.125 kg/ha at 20 DAS with 3 nutrient-management treatments, viz. NPK, NPK + Zn and NPKS + Zn, thereby making 27 treatment combinations. The experiment was laid out in a split-plot design, assigning weed-management to main plots and nutrient-management in subplots. The treatments were replicated thrice. Maize cv. Pratap QPM-1 was sown at the seed rate of 20 kg/ha at an inter-row spacing of 60 cm and plant-to-plant spacing of 25 cm. Furrows were opened through *desi* plough and seeds were sown manually at the depth of 5 cm. As per the treatment full dose of phosphorus (60 kg P<sub>2</sub>O<sub>5</sub>), potash (30 kg K<sub>2</sub>O), sulphur (40 kg S) and zinc (5 kg Zn) and half dose of nitrogen (60 kg N) were applied at sowing by drilling in crop rows through urea, diammonium phosphate, mineral gypsum and zinc sulphate. The remaining dose of nitrogen was top-dressed at knee height stage (35 days after sowing) through urea. As per treatment, both atrazine 0.5 kg/ha and alachlor 2.0 kg/ha were sprayed a day after sowing (as pre-emergence), while tembotrione 0.125 kg/ha was applied 20 days after sowing (as post-emergence) with knapsack sprayer. In each plot narrow and broad-leaf weeds were counted from 2 randomly selected area of 0.25 m<sup>2</sup> using 0.5 m × 0.5 m quadrat and expressed as number/m<sup>2</sup>. The mean data were subjected to square-root transformation  $\sqrt{(x+0.5)}$  to normalize their distribution. These weeds were dried at 65°C temperature in

oven till a constant weight was obtained which was expressed as weed dry matter in terms of g/m<sup>2</sup>. Economics of different treatment combinations were worked out in terms of net returns/ha and benefit: cost (B:C) ratio.

## RESULTS AND DISCUSSION

### Weed flora

In 2 years of field study, QPM was mainly infested with mixed flora of narrow and broad-leaf weeds, viz. 29.5% barnyard grass [*Echinochloa colona* (L.) Pers.], 6.5% bermuda grass [*Cynodon dactylon* (L.)], 6.3% nut grass [*Cyperus rotundus* (L.)], 12.5% viper grass [*Dinebra retroflexa* (Vahl) Panz.], 6.5% para grass [*Brachiaria reptans* (L.) C.A. Gardner & C.E. Hubb], 6.9% green amaranth [*Amaranthus viridis* (L.)], 7.8% false amaranth [*Digera muricata* (L.) Mart.], 14.8% desert horse purslane [*Trianthema portulacastrum* (L.)] and 10% tropical spiderwort [*Commelina benghalensis* (L.)] in weedy check at 60 DAS respectively (Table 1).

### Effect on weeds

All the weed-management treatments significantly reduced the weed density of narrow-leaf weeds, broad-leaf weeds and total weeds as well as their dry-matter accumulation at various growth stages during both the years. The data showed that, barnyard grass was most dominating weed at the experimental sites. Atrazine *fb* tembotrione was found to be the most effective in controlling weeds and dry matter of all the weeds at all stages compared to the other treatments. The data of total weed density and dry matter at all successive stages indicated overall superiority, in controlling the weeds, of atrazine *fb* tembotrione followed by alachlor *fb* tembotrione, 2 hand-weedings and alachlor + atrazine *fb* hand-weeding (Table 2). The combination of atrazine *fb* tembotrione was more effective and had activity on a wide spectrum of weeds including grasses and broad-leaf weeds. Atrazine belongs to triazines group of herbicides which are widely known to inhibit growth of emerged seedlings. Alachlor applied as pre-emergence inhibits seed germination by interfering with the metabolic activities, i.e. inhibition of  $\alpha$ -amylase and protease production induced by GA<sub>3</sub>. Tembotrione is currently registered as an important post-emergence herbicide in corn (*Zea mays* L.) and has showed quite satisfactory results on weed control, particularly for grasses (Waddington and Young, 2006). As a member of the triketone family of active ingredients, tembotrione shows properties of a weak acid and 4-Hydroxyphenylpyruvate dioxygenase (HPPD) inhibitor. 2 hand-weedings at 15 and 35 DAS removed the weeds completely and created condition more favourable for crop growth and ultimately resulted in the lowest density of later-emerged weeds and their lowest biomass with higher

**Table 1.** Effect of weed-management and nutrient-management on weed density at 60 days after sowing in quality protein maize (pooled data of 2 years)

| Treatment  | Weed density (No./m <sup>2</sup> ) |                         |                         |                           |                           |                           |                        |                                  |                               |  |
|--|------------------------------------|-------------------------|-------------------------|---------------------------|---------------------------|---------------------------|------------------------|----------------------------------|-------------------------------|--|
|  | <i>Echinochloa colona</i>          | <i>Cynodon dactylon</i> | <i>Cyperus rotundus</i> | <i>Dinebra retroflexa</i> | <i>Brachiaria reptans</i> | <i>Amaranthus viridis</i> | <i>Digera muricata</i> | <i>Trianthema portulacastrum</i> | <i>Commelina benghalensis</i> |  |
| <i>Weed management</i>   |                                    |                         |                         |                           |                           |                           |                        |                                  |                               |  |
| Weedy check  | 9.55*<br>(90.72)                   | 4.53<br>(20.08)         | 4.44<br>(19.29)         | 6.22<br>(38.28)           | 4.52<br>(19.99)           | 4.65<br>(21.18)           | 4.68<br>(21.48)        | 6.76<br>(45.29)                  | 5.56<br>(30.60)               |  |
| Hand-weeding 15 and 35 DAS   | 2.51<br>(5.82)                     | 2.84<br>(7.59)          | 2.98<br>(8.44)          | 2.69<br>(6.85)            | 2.61<br>(6.37)            | 2.85<br>(7.65)            | 2.62<br>(6.45)         | 3.84<br>(14.28)                  | 2.69<br>(6.95)                |  |
| Tembotrione 0.125 kg/ha at 20 DAS                                      | 3.22<br>(9.89)                     | 3.20<br>(9.77)          | 3.27<br>(10.20)         | 3.47<br>(11.56)           | 3.01<br>(8.57)            | 3.33<br>(10.62)           | 3.20<br>(9.77)         | 4.09<br>(16.26)                  | 3.20<br>(9.75)                |  |
| Alachlor 2 kg/ha/ <i>fb</i> hand-weeding at 35 DAS                     | 2.96<br>(8.28)                     | 3.03<br>(8.70)          | 3.15<br>(9.45)          | 3.29<br>(10.39)           | 2.98<br>(8.37)            | 3.20<br>(9.74)            | 3.03<br>(8.75)         | 4.05<br>(15.89)                  | 3.00<br>(8.53)                |  |
| Atrazine 0.5 kg/ha/ <i>fb</i> hand-weeding at 35 DAS                   | 2.93<br>(8.15)                     | 2.97<br>(8.39)          | 3.10<br>(9.14)          | 3.26<br>(10.14)           | 2.94<br>(8.17)            | 3.11<br>(9.20)            | 2.96<br>(8.27)         | 4.00<br>(15.54)                  | 2.96<br>(8.26)                |  |
| Tembotrione 0.125 kg/ha at 20 DAS                                      | 3.10<br>(9.17)                     | 3.16<br>(9.49)          | 3.23<br>(9.96)          | 3.42<br>(11.20)           | 2.99<br>(8.46)            | 3.30<br>(10.40)           | 3.13<br>(9.34)         | 4.06<br>(16.01)                  | 3.15<br>(9.47)                |  |
| <i>fb</i> hand-weeding at 35 DAS                                       | 2.67<br>(6.61)                     | 2.91<br>(8.00)          | 3.19<br>(9.71)          | 2.75<br>(7.09)            | 2.84<br>(7.57)            | 2.95<br>(8.20)            | 2.80<br>(7.40)         | 3.88<br>(14.58)                  | 2.83<br>(7.55)                |  |
| Alachlor 2 kg/ha + atrazine 0.5 kg/ha <i>fb</i> hand weeding at 35 DAS | 2.45<br>(5.55)                     | 2.89<br>(7.88)          | 3.08<br>(9.01)          | 2.72<br>(6.93)            | 2.68<br>(6.69)            | 2.88<br>(7.80)            | 2.74<br>(7.05)         | 3.84<br>(14.24)                  | 2.81<br>(7.41)                |  |
| Alachlor 2 kg/ha/ <i>fb</i> Tembotrione 0.125 kg/ha at 20 DAS          | 2.37<br>(5.15)                     | 2.80<br>(7.34)          | 3.02<br>(8.62)          | 2.60<br>(6.25)            | 2.64<br>(6.45)            | 2.81<br>(7.39)            | 2.71<br>(6.84)         | 3.80<br>(13.94)                  | 2.79<br>(7.29)                |  |
| Atrazine 0.5 kg/ha/ <i>fb</i> Tembotrione 0.125 kg/ha at 20 DAS        | 0.04<br>(0.10)                     | 0.04<br>(0.11)          | 0.04<br>(0.11)          | 0.05<br>(0.14)            | 0.03<br>(0.07)            | 0.03<br>(0.09)            | 0.05<br>(0.13)         | 0.04<br>(0.10)                   | 0.05<br>(0.13)                |  |
| SEm±<br>CD ( <i>P</i> =0.05)   |                                    |                         |                         |                           |                           |                           |                        |                                  |                               |  |
| <i>Nutrient-management</i>   |                                    |                         |                         |                           |                           |                           |                        |                                  |                               |  |
| NPK  | 3.52<br>(16.51)                    | 3.14<br>(9.62)          | 3.27<br>(10.42)         | 3.37<br>(12.03)           | 3.02<br>(8.95)            | 3.23<br>(10.22)           | 3.30<br>(11.35)        | 4.26<br>(18.44)                  | 3.22<br>(10.65)               |  |
| NPK + Zn   | 3.53<br>(16.63)                    | 3.15<br>(9.73)          | 3.27<br>(10.43)         | 3.37<br>(12.05)           | 3.03<br>(8.98)            | 3.23<br>(10.22)           | 3.29<br>(11.30)        | 4.26<br>(18.49)                  | 3.22<br>(10.65)               |  |
| NPKS + Zn  | 3.54<br>(16.64)                    | 3.15<br>(9.73)          | 3.27<br>(10.42)         | 3.39<br>(12.15)           | 3.02<br>(8.94)            | 3.24<br>(10.29)           | 3.29<br>(11.28)        | 4.25<br>(18.41)                  | 3.22<br>(10.64)               |  |
| SEm±<br>CD ( <i>P</i> =0.05)   | 0.01<br>NS                         | 0.02<br>NS              | 0.02<br>NS              | 0.03<br>NS                | 0.01<br>NS                | 0.02<br>NS                | 0.06<br>NS             | 0.01<br>NS                       | 0.03<br>NS                    |  |

DAS, days after sowing; PE, pre-emergence, *fb*, followed by

\*Data subjected to  $\sqrt{x+0.5}$  transformation and figures in parentheses are original weed count/m<sup>2</sup>

weed-control efficiency.

Among all the herbicide treatments, atrazine fb tembotrione exhibited the highest weed-control efficiency (72.1%) followed by alachlor fb tembotrione and 2 hand-weedings (Table 2). The possible reason might be owing to the fact that, performance of crop is directly proportional to the weed-control efficiency. The higher weed-control efficiency under these treatments could be attributed to the lower weed population and total weed dry matter as well. The reduction in weed dry matter owing to the application of herbicide combination can be attributed to their efficacy to control wide spectrum of weeds. Our results confirm the findings of Stanzen *et al.*, (2016) and Rana *et al.*, (2017). Varying nutrient-management treatments failed to affect the weed density as well as dry matter (Table 2) in either of the years. However, profound effect of different nutrient-management treatments on weeds has also been reported by Owla *et al.*, (2015).

**Effect on crop**

The highest yield-attributing characters, viz. grains/cob (367.9), grain weight (82.8 g), 1,000-seed weight (212.0 g) and shelling (76.6 %), were recorded under atrazine fb tembotrione followed by alachlor fb tembotrione and 2 hand-weedings at 15 and 35 DAS (Table 3). The better expression of yield attributes in herbicides treated and

**Table 2.** Effect of weed-management and nutrient-management on weed density, dry matter and weed-control efficiency in quality protein maize (pooled data of 2 years)

| Treatment  | Weed-density at 60 DAS (No./m <sup>2</sup> ) |                  |               | Weed dry-matter at harvesting (g/m <sup>2</sup> ) |                  |             | Weed-control efficiency at harvesting (%) |                  |             |
|--|--|------------------|---------------|---|------------------|-------------|---|------------------|-------------|
|  | Narrow-leaf weeds                            | Broad-leaf weeds | Total weeds   | Narrow-leaf weeds                                 | Broad-leaf weeds | Total weeds | Narrow-leaf weeds                         | Broad-leaf weeds | Total weeds |
| <b>Weed management</b>   |  |                  |               |   |                  |             |   |                  |             |
| Weedy check  | 13.74* (188.4)                               | 10.90 (118.6)    | 17.52 (306.9) | 243.08  | 235.03           | 478.11      | 0.00                                      | 0.00             | 0.00        |
| Hand-weeding 15 & 35 DAS                                       | 5.96 (35.07)                                 | 5.98 (35.33)     | 8.41 (70.40)  | 69.72   | 65.62            | 135.35      | 71.27                                     | 72.05            | 71.67       |
| Tembotrione 0.125 kg/ha at 20 DAS                              | 7.10 (49.99)                                 | 6.85 (46.40)     | 9.84 (96.39)  | 119.89  | 116.17           | 236.06      | 50.62                                     | 50.56            | 50.61       |
| Alachlor 2 kg/ha,fb hand weeding at 35 DAS                     | 6.76 (45.20)                                 | 6.59 (42.90)     | 9.41 (88.10)  | 91.75   | 89.11            | 180.86      | 62.22                                     | 62.09            | 62.17       |
| Atrazine 0.5 kg/ha,fb hand weeding at 35 DAS                   | 6.67 (43.99)                                 | 6.46 (41.28)     | 9.26 (85.27)  | 87.36   | 85.18            | 172.53      | 64.01                                     | 63.74            | 63.89       |
| Tembotrione 0.125 kg/ha at 20 DAS fb hand weeding at 35 DAS    | 6.98 (48.28)                                 | 6.76 (45.23)     | 9.69 (93.51)  | 100.81  | 97.12            | 197.93      | 58.47                                     | 58.64            | 58.57       |
| Alachlor 2 kg/ha +atrazine 0.5 kg/ha fb hand weeding at 35 DAS | 6.28 (38.99)                                 | 6.18 (37.73)     | 8.78 (76.72)  | 75.01   | 70.19            | 145.19      | 69.11                                     | 70.12            | 69.61       |
| Alachlor fb Tembotrione 0.125 kg/ha at 20 DAS                  | 6.04 (36.06)                                 | 6.08 (36.50)     | 8.54 (72.56)  | 69.62   | 64.75            | 134.38      | 71.32                                     | 72.45            | 71.88       |
| Atrazine fb Tembotrione 0.125 kg/ha at 20 DAS                  | 5.86 (33.81)                                 | 5.99 (35.46)     | 8.35 (69.27)  | 68.93   | 64.64            | 133.57      | 71.61                                     | 72.51            | 72.07       |
| SEM±   | 0.05   | 0.06             | 0.07          | 0.83  | 1.21             | 1.85        | -   | -                | -           |
| CD (P=0.05)  | 0.15   | 0.16             | 0.20          | 2.40  | 3.48             | 5.32        | -   | -                | -           |
| <b>Nutrient-management</b>                                     |  |                  |               |   |                  |             |   |                  |             |
| NPK  | 7.25 (57.54)                                 | 6.87 (48.83)     | 9.97 (106.4)  | 102.44  | 97.99            | 200.43      | -   | -                | -           |
| NPK + Zn   | 7.27 (57.82)                                 | 6.87 (48.87)     | 9.99 (106.7)  | 102.64  | 98.33            | 200.97      | -   | -                | -           |
| NPKS + Zn  | 7.27 (57.89)                                 | 6.86 (48.76)     | 9.98 (106.6)  | 103.70  | 99.62            | 203.32      | -   | -                | -           |
| SEM±   | 0.02   | 0.02             | 0.03          | 0.26  | 0.28             | 0.40        | -   | -                | -           |
| CD (P=0.05)  | NS   | NS               | NS            | 0.73  | 0.80             | 1.13        | -   | -                | -           |

DAS, Days after sowing; PE, pre-emergence; fb, followed by

\*Data subjected to  $\sqrt{x+0.5}$  transformation and figures in parentheses are original weed count/m<sup>2</sup>

manually weeded plots might be owing to poor resurgence frequency, growth of weeds and better weed control in these treatments. Hence, weeds were unable to compete with the crop plants for different growth factors. Improvement in yield attributes occurred when weeds were controlled in the early growth stages, particularly during the critical growth period either manually or chemically, which brought down competition and created congenial micro-environment for better establishment and growth of the crop. By controlling weeds with the use of different measures significantly higher grain (4.5 t/ha) and stover (7.5 t/ha) yield were recorded (Table 3). Atrazine/*fb* tembotrione followed by alachlor/*fb* tembotrione and 2 hand-weedings were found significantly superior in this regard. The increased grain and stover yields were obviously the results of better weed management. Owla *et al.*, (2015) and Rana *et al.*, (2017) also reported similar results. Nutrient application of NPKS + Zn resulted in significantly higher yield attributes, viz. grains/cobs, grain weight, 1,000-seed weight and shelling %. Across the years, different nutrient-management treatments resulted in increased grain, stover yield of QPM, and application of NPKS + Zn gave maximum grain (4.3 t/ha) and stover (7.2 t/ha) yield. Significant increase in grain and stover yields owing to application of NPKS + Zn could be ascribed to the fact that, yield of the crop is a function of several yield components, i.e. grains/cobs, grain weight (g/plant) and 1,000-seed weight (g) etc.

It may be owing to beneficial effect of sulphur on crop growth and development and improvement in nutritional status of plant parts (grain and stover), which affected the yield and nutritional positively. Application of Zn along with NPK significantly increased the grains/cobs. Zinc therefore is the main yield-limiting plant nutrient in Rajasthan. Zinc is reported to enhance the absorption of native as well as added major nutrients such as N and P, thereby the increased yield attributes and production of maize. The results of present investigation indicated higher production of maize under influence of balanced fertilization are in close conformity with findings of Gul and Kaday (2015) and Joshi *et al.*, (2016).

### Economics

The minimum net monetary returns were fetched under weedy check plots as a result of the lowest grain and stover yields (Table 3). However, pre-emergence atrazine with post-emergence tembotrione was found most remunerative, as it fetched the highest net returns (₹ 68.9 × 10<sup>3</sup>/ha) and benefit : cost ratio (2.6). The low investment under different herbicide application coupled with good economic yield might be the reason for higher net monetary return and benefit: cost ratio, even 2 hand-weedings resulted in the maximum gross monetary return but was nullified due to higher labour cost for weed management. Similar findings were also reported by Owla *et al.*, (2015). Under

**Table 3.** Effect of weed-management and nutrient-management on yield attributes, yield and economics of quality protein maize (pooled data of 2 years)

| Treatment  | Grains/cob | Grain weight (g/plant) | 1,000-seed weight (g) | Shelling (%) | Grain yield (t/ha) | Stover yield (t/ha) | Net reruns (₹ × 10 <sup>3</sup> /ha) | Benefit: cost ratio |
|--|------------|------------------------|-----------------------|--------------|--------------------|---------------------|--------------------------------------|---------------------|
| <i>Weed management</i>   |            |                        |                       |              |                    |                     |                                      |                     |
| Weedy check  | 264.3      | 53.5                   | 154.6                 | 69.4         | 2.6                | 4.7                 | 33.1                                 | 1.4                 |
| Hand-weeding 15 and 35 DAS   | 358.9      | 80.8                   | 204.6                 | 75.5         | 4.5                | 7.4                 | 63.7                                 | 2.1                 |
| Tembotrione 0.125 kg/ha at 20 DAS                                      | 304.5      | 71.1                   | 172.8                 | 69.7         | 4.0                | 7.0                 | 60.8                                 | 2.4                 |
| Alachlor 2 kg/ha <i>fb</i> hand weeding at 35 DAS                      | 309.9      | 75.0                   | 180.7                 | 71.3         | 4.2                | 7.1                 | 62.1                                 | 2.4                 |
| Atrazine 0.5 kg/ha <i>fb</i> hand weeding at 35 DAS                    | 316.8      | 76.7                   | 183.6                 | 71.8         | 4.3                | 7.2                 | 64.7                                 | 2.5                 |
| Tembotrione 0.125 kg/ha at 20 DAS <i>fb</i> hand weeding at 35 DAS     | 307.5      | 73.1                   | 176.8                 | 72.1         | 4.1                | 7.1                 | 60.0                                 | 2.2                 |
| Alachlor 2 kg/ha + atrazine 0.5 kg/ha <i>fb</i> hand weeding at 35 DAS | 327.2      | 77.7                   | 196.6                 | 74.1         | 4.3                | 7.2                 | 64.3                                 | 2.4                 |
| Alachlor 2 kg/ha <i>fb</i> Tembotrione 0.125 kg/ha at 20 DAS           | 361.9      | 81.9                   | 206.9                 | 74.5         | 4.5                | 7.4                 | 68.4                                 | 2.6                 |
| Atrazine 0.5 kg/ha <i>fb</i> Tembotrione 0.125 kg/ha at 20 DAS         | 367.9      | 82.8                   | 212.0                 | 76.6         | 4.5                | 7.5                 | 68.9                                 | 2.6                 |
| SEm±   | 3.3        | 0.5                    | 0.8                   | 0.8          | 0.9                | 1.3                 | 1.7                                  | -                   |
| CD (P=0.05)  | 9.4        | 1.4                    | 2.3                   | 2.2          | 2.8                | 3.8                 | 5.0                                  | -                   |
| <i>Nutrient-management</i>   |            |                        |                       |              |                    |                     |                                      |                     |
| NPK  | 320.4      | 73.9                   | 186.6                 | 72.2         | 4.0                | 6.7                 | 59.9                                 | 2.46                |
| NPK + Zn   | 324.1      | 74.5                   | 187.3                 | 72.6         | 4.1                | 6.9                 | 59.3                                 | 2.15                |
| NPKS + Zn  | 328.5      | 75.9                   | 189.0                 | 73.5         | 4.3                | 7.2                 | 62.9                                 | 2.28                |
| SEm±   | 1.5        | 0.2                    | 0.4                   | 0.4          | 0.4                | 0.5                 | 0.7                                  | -                   |
| CD (P=0.05)  | 4.1        | 0.4                    | 1.1                   | 1.2          | 1.1                | 1.4                 | 1.9                                  | -                   |

DAS, Days after sowing; PE, pre-emergence, *fb*, followed by

different nutrient-management treatments, application of NPKS + Zn provided significantly higher net returns ( $\text{₹ } 62.8 \times 10^3/\text{ha}$ ), while benefit : cost ratio (2.46) remained the highest with NPK (Table 3). Increase in net realization might be because of increase in grain yield under NPKS + Zn. This is in accordance with the findings of Verma *et al.*, (2012).

On the basis of 2 years investigation on quality protein maize under the influence of weed and nutrient management, it emerged out that weed-management by atrazine 0.5 kg/ha as pre-emergence fb tembotrione 0.125 kg/ha at 20 DAS showed the highest weed-control efficiency (72.07%) and grain yield (4.5 t/ha). Under the nutrient-management, application of 120 kg N + 60 kg P<sub>2</sub>O<sub>5</sub> + 30 kg K<sub>2</sub>O along with 40 kg S and 5 kg Zn/ha resulted in the highest grain yield (4.3 t/ha). Similarly, in monetary terms the maximum net returns ( $\text{₹ } 68.9 \times 10^3/\text{ha}$ ) and benefit: cost ratio (2.64) were observed under application of atrazine fb tembotrione. Amongst the nutrient-management options, an addition of Zn and S with NPK ensued in the highest net returns ( $\text{₹ } 62.8 \times 10^3/\text{ha}$ ), while maximum B:C (2.46) was recorded with NPK.

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