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Study of Real -time nitrogen management and sustainable weed management practices on maize productivity

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ABSTRACT

A field experiment was conducted during two consecutive kharif 2019 and 2020 on sandy loam soils of S.V. Agricultural College, Tirupati, Andhra Pradesh. The field experiment was laid out in a split-plot design with three replications. The treatments comprised of four nitrogen management practices viz., control (N_1), recommended dose of fertilizer (N_2), green seeker directed N application (N_3) and soil test based fertilizer application (N_4) assigned to main plots and nine weed management practices viz., unweeded check (W_1), hand weeding twice at 15 and 30 DAS (W_2), pre emergence application of atrazine 1.0 kg ha^{-1} fb post emergence application of topramezone 30 g ha^{-1} (W_3), pre emergence application of atrazine 1.0 kg ha^{-1} fb post emergence application of tembotrione 120 g ha^{-1} (W_4), application of parthenium water extract 15 l ha^{-1} twice at 15 and 30 DAS (W_5), application of sunflower water extract 15 l ha^{-1} twice at 15 and 30 DAS (W_6), pre emergence application of atrazine 1.0 kg ha^{-1} fb post emergence application of parthenium water extract 15 l ha^{-1} (W_7), pre emergence application of atrazine 1.0 kg ha^{-1} fb post emergence application of sunflower water extract 15 l ha^{-1} (W_8) and brown manuring (W_9) allotted to subplots. Growth parameters of maize, yield attributes, and yield were higher with green seeker-directed N application (N_3). Control (N_1) recorded significantly lower values during both the years of study and in the pooled mean. With regard to weed management practices, significantly higher values were produced with hand weeding twice at 15 and 30 DAS (W_2), which was however, in parity with pre-emergence application of atrazine 1.0 kg ha^{-1} fb post-emergence application of topramezone 30 g ha^{-1} (W_3) and pre emergence application of atrazine 1.0 kg ha^{-1} fb post-emergence application of tembotrione 120 g ha^{-1} (W_4). Lower values of growth parameters were recorded with an unweeded check (W_1). Significant interaction between nitrogen and weed management practices was observed with dry matter production, cob length, kernel weight cob^{-1}, kernel yield and stover yield. Higher and lower values were recorded with green seeker-directed N application along with hand weeding twice at 15 and 30 DAS (N_3W_2) and control coupled with an unweeded check (N_1W_1) respectively during both the years of study and in pooled mean.

Keywords: *Nitrogen, Green seeker, Weed, Water extract Brown manuring, and Postemergence*

INTRODUCTION

Maize is an exhaustive crop and highly responsive to nitrogen fertilizers. The crop demand driven site-specific nitrogen application has the potential to add to productivity and farmers' profits and is crucial for achieving high yield and nitrogen use efficiency. The real-time nitrogen management approach can help to increase nitrogen use efficiency by matching the time of fertilizer application with plant need. In real-time nitrogen management, the timing of nitrogen fertilizer applications is determined through periodic monitoring of crop nitrogen status [4]. Crop reflectance sensors provide an accurate and spatially-intensive method for diagnosing and applying the correct nitrogen rate. Green seeker optical sensor is emerging as tool for real-time nitrogen fertilizer management in cereals. It determines the fertilizer rate based on plants' normalized difference vegetation index (NDVI). As it is able to detect N stress and crop vigor, it is widely used as the basis for nitrogen application. NDVI values range from -1 to + 1, with higher values indicating better plant health [7].

Maize being a widely spaced crop, mostly grown in the rainy season gets infested with adverse weeds and is liable to excessive weed competition, which often inflicts huge losses ranging from 27-60 per cent depending upon the growth and persistence of the weed population [25]. Initially, manual and mechanical management of weeds is widely accepted, but, often difficult due to scarcity of labour, reduced labour efficiency, and difficulty in operating machines during unfavorable conditions and higher expenditure [23]. In such conditions, chemical method of weed control using pre or post-emergence herbicides is an obvious choice during the critical period of crop weed competition [12]. Most of the herbicides currently available in the market provide only a narrow-spectrum of weed control in maize. Continuous use of these herbicides for a long time may lead to the development of herbicide resistance in weeds [14]. The evolution of herbicide resistance in a large number of weed species across the world has further aggravated the situation. Sustainable weed management is a key option to achieve better crop yield with ecological balance. It must have a harmony with

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chemical and non-chemical options that can be used judiciously in order to achieve rational weed control. Hence, it is required to redesign weed management strategies with the usage of new-generation herbicides, use of cover crops, brown manuring, and spraying of botanicals.

Nitrogen fertilizer application can affect weed germination and establishment. Weeds not only reduce the amount of nitrogen available to crops but also result in crop suppression by excessive weed growth under inappropriate nitrogen fertilization. Proper nitrogen splitting may reduce weed interference in crops. Hence, it is imperative that crop-weed competitive interactions can be altered by nitrogen fertilizer dose and application timing [1]. Keeping in view the above perspectives, the present study was conducted to enhance maize productivity through real-time nitrogen management and sustainable weed management practices.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in Field No. 127 of Sri Venkateswara Agricultural College Dryland Farm, Tirupati campus of Acharya N.G. Ranga Agricultural University, which is geographically situated at 13.5°N latitude, 79.5°E longitude and at an altitude of 182.9 m above mean sea level in the Southern Agro-climatic Zone of Andhra Pradesh. According to Trolls classification, it is under Semi-Arid Tropics (SAT).

Physico-chemical properties of the experimental field

The composite soil sample was drawn at random from 0-30 cm soil depth of the field before the experimentation and analyzed for different physicochemical properties by adopting the standard procedures and the results are presented in Table 3.3. The results of soil analysis revealed that the soil was sandy loam in texture, neutral in soil reaction, low in organic carbon and available nitrogen and medium in available phosphorus and available potassium.

Table 1. Physico-chemical properties of the experimental field

Particulars	Value (2019)	Value (2020)	Method of analysis
A. Physical characteristics			
Sand (%)	67.8	67.8	Bouyoucos hydrometer [20]
Silt (%)	26.4	26.4	
Clay (%)	05.8	05.8	
Textural class	Sandy loam	Sandy loam	
B. Chemical characteristics			
Soil pH (1: 2.5 Soil water suspension)	6.85	6.89	Glass electrode pH meter [8]
EC (dS m^{-1})	0.18	0.19	Conductivity bridge [8]
Organic carbon (%)	0.27	0.28	Wet digestion method [29]
Available N (kg ha^{-1})	113.4	119.2	Alkaline permanganate method [26]
Available P_2O_5 (kg ha^{-1})	26.4	26.8	Olsen's method [17]
Available K_2O (kg ha^{-1})	180.9	191.3	Flame photometry [8]

Experimental details

The field experiment was laid out in a split-plot design with three replications. The treatments comprised of four nitrogen management practices *viz.*, control, recommended dose of fertilizer, green seeker directed N application, and soil test-based fertilizer application assigned to main plots. and nine weed management practices viz., unweeded check, hand weeding twice at 15 and 30 DAS, pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of topramezone 30 g/ha, pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of tembotrione 120 g/ha, application of parthenium water extract 15 l/ha twice at 15 and 30 DAS, application of sunflower water extract 15 l/ha twice at 15 and 30 DAS, pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of parthenium water extract 15 l/ha, pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of sunflower water extract 15 l/haand brown manuring.

Nitrogen was applied in the form of urea and no nitrogen was applied to the control plot. The recommended dose of 180 N/ha was applied in N_2. In green seeker-directed N application, 1/3rd of N was applied as basal and the remaining N was top dressed as per green seeker readings. Whenever these NDVI values fall below the threshold value at 0.8, nitrogen was top dressed at 25 kg/haimmediately to meet the N requirement irrespective of the stage of the crop [21]. The final split application of N was completed by 70 DAS coinciding with the silking stage (Table 2 and 3). The green seeker hand held optical sensor unit model 505 was used to measure NDVI (Normalized difference vegetative index) from the crop canopy. The sensor angle was adjusted in such a way that it was parallel to sensing area at a height of about 70 cm above the canopy. A photodiode detector within the sensor measures the magnitude of the light reflected from the target and NDVI was computed. The sensor displays the measured value on its LCD. Normalized difference vegetative index measurements made by Green seeker were computed by the following equation.

$$NDVI = \frac{NIR\ ref - RED\ ref}{NIR\ ref + RED\ ref}$$

where,

NIR ref or RED ref represents reflectance in the near-infrared and red bands.

In soil-test based N fertilizer application, an additional dose of 30 percent to the recommended dose of N fertilizer was applied (as the experimental field was low in available nitrogen). A uniform dose of 60 kg P_2O_5 and 50 kg K_2O ha^{-1} was applied to all plots.

Table 2. Quantity of nitrogen (kg ha^{-1}) applied under different nitrogen management practices

Treatments	Basal	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Total N applied
N_1: Control	-	-	-	-	-	-	-	-
N_2: Recommended dose of fertilizer	60	-	60	-	60	-	-	180.0
N_3: Green seeker directed N application	60	25	25	25	25	16.7	25	201.7
N_4: Soil test based fertilizer application	78	-	78	-	78	-	-	234.0

Table 3. Quantity of nitrogen (kg ha^{-1}) applied in N_3 under different weed management practices

Treatments	Basal	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Total N applied
N_3W_1	60	25	25	25	25	25	25	210
N_3W_2	60	25	25	25	25	-	25	185
N_3W_3	60	25	25	25	25	-	25	185
N_3W_4	60	25	25	25	25	-	25	185
N_3W_5	60	25	25	25	25	25	25	210
N_3W_6	60	25	25	25	25	25	25	210
N_3W_7	60	25	25	25	25	25	25	210
N_3W_8	60	25	25	25	25	25	25	210
N_3W_9	60	25	25	25	25	25	25	210

Hand weeding was done twice at 15 and 30 DAS in the treatment W_2. The required quantities of pre-emergence (atrazine) and post-emergence (tembotrione and topramezone) herbicides were sprayed uniformly on 2 and 15 DAS, respectively. The required quantities of filtered concentrated plant water extracts were sprayed at 15 and 30 DAS. In brown manuring treatment plots, *Sesbania* was grown in intermediate rows of maize and it was knocked down with 2,4 D at 1.0 kg/ha at 35 DAS. Maize hybrid DHM -117 was sown and maintained with all general cultivation practices except for nitrogen and weed management methods.

Preparation of plant water extracts

Carrot grass and sunflower were collected from the farmer's field at the flowering stage, dried under shade and stored at room temperature. The dried material of entire plant parts of carrot grass (*Parthenium hysterophorus* L.) and sunflower (*Helianthus annus* L.) were chopped with power-operated fodder cutter into 2 cm pieces, separately. The chopped plant material was soaked in distilled water for 24 hours at room temperature of 21°C with a ratio of 1:10 (w/v) and the same was filtered through 10 and 60 mesh sieves [2]. The initial volume of distilled water for soaking was 10 litres for every one kilogram of chopped material and after filtration, the final volume of the filtrate was seven litres. These extracts were separately boiled at 100°C to concentrate upto 20 times for easy handling and application as per the treatments. These concentrated water extracts were stored at room temperature.

Data Collection

Observations on Weeds

Observations on weed growth were recorded from randomly selected quadrant areas in each plot. Weed flora observed in different treatments was recorded separately and grouped as grasses, sedges, and broadleaved weeds. Weeds were categorized into grasses, sedges, and broadleaved weeds and expressed weed density as number m^{-2}. The data on weed density was analyzed through square root transformation by using the formula:

$$X = \sqrt{x + 0.5}$$

where, X = Transformed value, x = Original value. Weeds were collected from the quadrat of 0.25 m × 0.25 m and outside of the net plot and dried under shade for 24 hours followed by oven drying at 65°C to a constant weight and was expressed as Weed dry weight in g m^{-2}.

Growth parameters

Plant height was recorded from five tagged plants in each plot measured from the base of the plant to the tip of the tassel and the mean was expressed in cm. Leaf area was measured by using LICOR model LI-300 leaf area meter to record leaf area in cm^2. The leaf area index was calculated by dividing the total leaf area with the corresponding land area as suggested by Watson (1952).

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area (cm}^2\text{)}}$$

Dry matter production was recorded from destructive samples. Five plants were collected from outside the net plot area in each treatment leaving the extreme border row. These samples were shade-dried and later on oven-dried at 65°C to a constant weight. Then dry weights were recorded and expressed in kg ha^{-1}.

Yield attributes and Yield

The length of the cob was measured from the blunt end to the tip of the shank from each of the five labeled plants and the average was worked out and expressed in cm. Kernel weight cob^{-1} was calculated by Cobs collected from randomly selected five sample plants from net plot that were thoroughly sun-dried, threshed, and their weights were averaged and expressed in g. Kernel yield was obtained from Threshed, sun-dried, and cleaned kernels from each net plot were weighed and expressed as kg ha^{-1}. The stover from the net plot was thoroughly sundried to a constant weight, weighed, and expressed as stover yield kg ha^{-1}.

Statistical analysis

Data recorded on different parameters of maize was statistically analyzed following the analysis of variance for split-plot design [19].Statistical significance was tested with 'F' test at 5 percent level of probability and compared the treatment means with a critical difference. In view of larger variation in the recorded values of density and dry weight of weeds, the corresponding data were subjected

to square root transformation ($X = \sqrt{x + 0.5}$) and weed control efficiency was subjected to angular transformation before being subjected to statistical analysis [5].

RESULTS AND DISCUSSION

Weed flora

In a year field study, the maize-groundnut cropping sequence was infested with mixed flora belonging to sixteen taxonomic families of which four species were grasses, two species of sedges and sixteen species of broadleaved weeds. The predominant weed species noticed in the experimental field were *Cyperus rotundus* L., *Digitaria sanguinalis* (L). Scop., *Dactyloctenium aegyptium* (L.) Willd., *Blainvillea acmella* L., *Lagascea mollis* Cav. and *Commelina benghalensis* L [24] &[28].

Effect on weeds

The lower density and dry weight of grasses, sedges, broadleaved weeds as well as total weeds was registered with control. Recommended dose of fertilizer application and green seeker directed N application were at par with each other and were significantly lower than soil test-based fertilizer application, which recorded significantly higher density of grasses, sedges, broadleaved weeds and total weeds (Table 4). An initial higher dose of nitrogen application in soil test-based fertilizer application might have increased the weed biomass per unit area. Though higher density of weeds was noticed with fertilizer-applied treatments, marginal increase in density of weeds with fertilizer-applied treatments was less due to competitive ability of maize to suppress weed growth [10] &[11].

Among the different weed management practices, at 20 DAS hand weeding twice at 15 recorded significantly lower density and dry weight of grasses, sedges, broadleaved weeds, and total weeds over the rest of the treatments. At ٤٠ DAS, hand weeding twice at 15 and 30 DAS was at par with pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of topramezone 30 g/ha or tembotrione 120 g/ha. This was mainly attributed to the effective control of weeds with two-hand weedings or sequential application of pre and post-emergence herbicides [28].

Brown manuring was the next best weed management practice in reducing the dry weight of weeds. Pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of sunflower water extract 15 l/ha or parthenium water extract 15 l/ha were comparable with one another and were significantly lower than the application of sunflower water extract 15 l/ha or parthenium water extract 15 l/ha twice at 15 and 30 DAS. Pre-emergence application of atrazine *fb* post-emergence application of plant water extracts resulted in greater reduction in weed biomass than the plant water extracts alone.

The higher density and dry weight of all categories of weeds was recorded with unweeded check due to heavy weed infestation right from sowing to harvest of the crop [22] &[31]. None of their interaction effects were found to be significant during both years of study.

Effect on growth parameters

Nitrogen and weed management practices significantly influenced the plant height, Leaf area index and Dry matter production of maize during both the years of study as well as in pooled mean. The interaction effect of nitrogen and weed management practices on plant height and leaf area index was not statistically traceable, whereas exerted a significant influence on dry matter production.

Among nitrogen management practices, significantly the highest growth parameters were recorded with green seeker-directed N application (N_3). Application of nitrogen on-demand with the help of green seeker might have enhanced assimilation of carbohydrates might have increased the photosynthetic area, resulting in the form of higher plant height and leaf area index leading to higher dry matter production [15] [18]&[21].

The next best treatment was soil test based fertilizer application (N_4), which was significantly superior to the recommended dose of fertilizer application (N_2) while the latter two was superior to the control. Control (N_1) recorded the lower values during both the years of experimentation and in pooled mean.

With regard to weed management practices, significantly higher values of growth parameters were produced with hand weeding twice at 15 and 30 DAS (W_2), which was however, in parity with pre-emergence application of atrazine 1.0 kg ha^{-1} *fb* post emergence application of topramezone 30 g ha^{-1} (W_3) and pre-emergence application of atrazine 1.0 kg ha^{-1} *fb* post-emergence application of tembotrione 120 g ha^{-1} (W_4). This was owed to reduced weed density and dry weight during the critical stages of crop growth thus providing congenial environment due to which all the growth resources had been optimally utilized by the crop for better vegetative boom that reflected as plant height, higher leaf area index and enhanced photosynthates which in turn resulted in higher dry matter production [6] &[13].

With regard to interaction effect on dry matter production, significantly higher drymatter production was recorded with green seeker directed N application combined with hand weeding twice at 15 and 30 DAS (N_3W_2), which was comparable with green seeker directed N application combined with pre emergence application of atrazine 1.0 kg ha^{-1} *fb* post emergence application of topramezone 30 g ha^{-1} (N_3W_3), green seeker directed N application combined with pre-emergence application of atrazine 1.0 kg ha^{-1} *fb* post emergence application of tembotrione 120 g ha^{-1} (N_3W_4), soil test based fertilizer application combined with hand weeding twice at 15 and 30 DAS (N_4W_2), soil test based fertilizer application combined with pre emergence application of atrazine 1.0 kg ha^{-1} *fb* post emergence application of topramezone 30 g ha^{-1} (N_4W_3) and soil test based fertilizer combinedwith pre emergence application of atrazine 1.0 kg ha^{-1} *fb* post emergence application of tembotrione 120 g ha^{-1} (N_4W_4). Reduced weed competition and adequate availability of nutrients throughout the growth period might have increased the plant stature, leaf area index resulting in higher dry matter production. The lowest dry matter production was observed with control coupled with unweeded check (N_1W_1) which was comparable with same nitrogen management practice combined with application of parthenium water extract15 l ha^{-1} twice at 15 and 30 DAS (N_1W_5), application of sunflower water extract 15 l ha^{-1} twice at 15 and 30 DAS (N_1W_6), pre-emergence application of atrazine 1.0 kg ha^{-1} *fb* post emergence application of parthenium water extract 15 l ha^{-1} (N_1W_7) and pre-emergence application of atrazine1.0 kg ha^{-1} *fb* post emergence application of sunflower water extract 15 l ha^{-1} (N_1W_8) in the order of ascent during both the consecutive years of study and in pooled mean.

Effect on yield attributes and yield

Nitrogen and weed management practices as well as their interaction effect exerted significant influence on yield attributes and yield of maize during both the years of investigation as well as in pooled mean.

Among the nitrogen management practices, green seeker-directed N application recorded significantly higher yield attributes and yield of maize during both the years of study as well as in pooled mean. It might be due to precise nitrogen application in more splits compared to other treatments. Adequate supply of nitrogen at appropriate crop growth stages might have enhanced greater availability of nutrients in the soil which resulted in more absorption and higher uptake by the crop plants. This might be owing to better translocation and partitioning of assimilates from source to sink due to timely application of nitrogen-based on crop demand [9] &[21].

In the different weed management practices evaluated, higher values of yield attributes and Yield were observed with hand weeding twice at 15 and 30 DAS. However, it was on par with application of atrazine 1.0 kg/ha as pre-emergence *fb* topramezone 30 g/ha as post-emergence, atrazine 1.0 kg/ha as pre-emergence *fb* tembotrione 120 g/ha as post-emergence without any significant disparity among them during both the years of study and in pooled mean (Table 7-10). This might be due to better partitioning of photosynthates from source to sink as a result of decreased competition for growth resources under weed free environment, which led to more accumulation and efficient translocation of assimilates from source to sink, which inturn reflected in the form of yield attributes and Yield maize [13] &[27]. Lower values were resulted with weedy check during both the years of study and in pooled mean.

With regard to interaction effect, significantly higher values were recorded with green seeker directed N application with hand weeding twice at 15 and 30 DAS but it was on par with green seeker directed N application along with pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of topramezone 30 g/ha, green seeker directed N application and pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of tembotrione 120 g/ha, soil test based fertilizer application combined with hand weeding twice at 15 and 30 DAS, soil test based fertilizer application combined with pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of topramezone 30 g/ha and soil test based fertilizer application combined with pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of tembotrione 120 g/ha. Significantly higher kernel yield in these treatment combinations might be due to maintenance of weed free environment during critical period of crop weed competition and sensor determined topdressing of nitrogen for maize with increased number of split applications leading to increased availability of growth resources at distinct physiological phases and better translocation of photosynthates to sink resulting in higher growth and yield attributes leading to higher kernel and stover yield[3]&[16].The lowest kernel and stover yields were observed with control coupled with unweeded check, which was comparable with control coupled with the application of parthenium water extract 15 l/ha twice at 15 and 30 DAS, control coupled with application of sunflower water extract 15 l/ha twice at 15 and 30 DAS, control coupled with pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of parthenium water extract 15 l/ha and control coupled with the pre-emergence application of atrazine 1.0 kg/ha *fb* post-emergence application of sunflower water extract 15 l/ha in the order of ascent during both the years of study.

Conclusion

In conclusion, the present study revealed that green seeker directed N application at 201.7 N kg ha^{-1} along with pre-emergence application of atrazine 1.0 kg ha^{-1} *fb* post-emergence application of topramezone 30 g ha^{-1} or tembotrione 120 g ha^{-1} were considered to be the most effective practices to increase the productivity in maize.

Future scope of the study: Standardization of threshold values of green seeker for in soil, grain different potential maize varieties and hybrids. The research may be undertaken at several locations to make concrete recommendations for maize growers. Developing a valuable short-term forecasting tool for nutrient management can assist producers and planners in making daily decisions by quickly identifying high-risk environmental conditions. Need for research on nitrogen losses and information on weed dynamics under nitrogen and weed management studies need to be generated.

Conflict of interest: The authors have declared that no conflict of interest exist

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Table 4. Effect of nitrogen and weed management practices on total weed density and weed dry weight in maize

Treatment	Total weed density (no. m^{-2})				Total weed dry weight (g m^{-2})			
	20 DAS		40 DAS		20 DAS		40 DAS	
Nitrogen management	2019	2020	2019	2020	2019	2020	2019	2020
Control	6.07 (42.89)	7.33 (62.66)	5.26 (33.67)	5.54 (37.49)	7.16 (67.74)	8.06 (86.32)	6.34 (52.86)	6.59 (57.14)
Recommended dose of fertilizer	7.71 (68.79)	9.29 (99.67)	7.35 (64.26)	7.73 (71.02)	8.20 (89.31)	9.44 (118.36)	7.93 (83.65)	8.45 (95.09)
Green seeker directed N application	7.83 (73.41)	9.43 (106.24)	7.66 (69.92)	8.07 (77.44)	8.55 (96.02)	9.66 (122.57)	8.20 (88.61)	8.80 (102.20)
Soil test based fertilizer application	8.80 (97.20)	10.38 (134.39)	8.60 (85.59)	8.78 (89.00)	9.69 (122.72)	10.69 (148.92)	9.20 (110.87)	9.65 (121.91)
LSD (P = 0.05)	0.73	0.89	0.52	0.56	0.74	0.99	0.61	0.67
Weed management								

Unweeded check	11.12 (132.82)	13.29 (188.90)	10.56 (119.72)	11.02 (130.26)	14.55 (214.49)	15.90 (255.07)	13.72 (191.99)	14.50 (214.63)
Hand weeding twice at 15 and 30 DAS	0.71 (0.00)	1.13 (1.00)	0.71 (0.00)	0.79 (0.14)	2.24 (4.62)	2.50 (5.94)	2.12 (4.12)	2.23 (4.63)
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of topramezone @ 30 g/ha	6.24 (40.82)	7.44 (58.24)	6.33 (41.70)	6.60 (45.36)	2.46 (5.92)	2.75 (7.56)	2.33 (5.28)	2.46 (5.94)
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of tembotrione @ 120 g/ha	6.68 (45.55)	7.98 (65.10)	6.49 (44.01)	6.78 (47.88)	2.70 (6.99)	3.04 (8.96)	2.56 (6.22)	2.70 (7.00)
Application of parthenium water extract @ 15 l/ha twice at 15 and 30 DAS	10.96 (127.67)	13.09 (181.51)	10.27 (108.36)	10.72 (117.94)	13.06 (173.54)	14.87 (224.80)	12.31 (155.46)	13.01 (173.79)
Application of sunflower water extract @ 15 l/ha twice at 15 and 30 DAS	10.93 (125.82)	13.06 (179.15)	10.33 (108.70)	10.73 (117.13)	12.66 (162.99)	14.42 (211.24)	11.94 (146.02)	12.63 (163.47)
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of parthenium water extract @ 15 l/ha	6.77 (46.79)	8.09 (66.85)	6.45 (44.23)	6.72 (47.88)	11.05 (122.19)	12.57 (158.45)	10.39 (108.76)	10.99 (121.90)
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of sunflower water extract @ 15 l/ha	6.67 (45.24)	7.97 (64.85)	6.31 (42.32)	6.58 (45.83)	10.82 (117.20)	12.32 (151.96)	10.18 (104.36)	10.77 (116.99)
Brown manuring	8.30 (70.44)	9.94 (101.01)	7.53 (61.20)	7.85 (66.23)	6.05 (37.57)	6.79 (47.38)	5.72 (33.77)	6.10 (38.44)
LSD (P = 0.05)	0.96	1.15	1.04	1.09	1.05	1.20	1.07	1.13
N at W								
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
W at N								
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Data in parenthesis are original values, which were transformed to ($\sqrt{X+0.5}$) and analysed statistically

Table 5. Growth parameters at harvest of maize as influenced by nitrogen and weed management practices

Treatments	**Plant height (Cm)**			**Leaf area index**			**Dry matter production (kg ha^{-1})**		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
Nitrogen management practices									
N_1 : Control	110	101	106	1.77	1.69	1.73	5857	5706	5782
N_2 : Recommended dose of fertilizer	184	177	181	2.06	1.94	2.00	9523	9223	9373
N_3 : Green seeker directed N application	222	213	218	2.46	2.41	2.44	12472	12152	12312
N_4 : Soil test based fertilizer application	203	195	199	2.30	2.23	2.26	11675	11256	11465
SEm ±	4.3	4.2	4.2	0.060	0.055	0.053	238.0	248.0	235.4
CD (P = 0.05)	15	16	15	0.21	0.19	0.17	824	858	815
Weed management practices									
W_1 : Unweeded check	143	135	139	1.61	1.45	1.53	6835	6502	6668
W_2 : Hand weeding twice at 15 and 30 DAS	215	201	208	2.66	2.60	2.63	13497	13181	13339
W_3 : PE application of atrazine @ 1.0 kg ha^{-1} *fb* PoE application of topramezone @ 30 g ha^{-1}	211	203	207	2.63	2.56	2.60	13241	12908	13074
W_4 : PE application of atrazine @ 1.0 kg ha^{-1} *fb* PoE application of tembotrione @ 120 g ha^{-1}	207	199	203	2.60	2.53	2.57	13011	12736	12874
W_5 : Application of parthenium water extract @ 15 l ha^{-1} twice at 15 and 30 DAS	160	153	156	1.86	1.80	1.83	7550	7392	7471
W_6 : Application of sunflower water extract @ 15 l ha^{-1} twice at 15 and 30 DAS	163	155	159	1.88	1.80	1.84	7692	7509	7600
W_7 : PE application of atrazine @ 1.0 kg ha^{-1} *fb* PoE application of parthenium water extract @ 15 l ha^{-1}	165	157	161	1.90	1.82	1.86	7866	7533	7699
W_8 : PE application of atrazine @ 1.0 kg ha^{-1} *fb* PoE application of sunflower water extract @ 15 l ha^{-1}	168	160	164	1.89	1.81	1.85	8071	7738	7904
W_9 : Brown manuring	189	183	186	2.31	2.23	2.27	11174	10761	10967
SEm ±	5.2	5.4	5.3	0.088	0.085	0.084	301.3	276.5	270.2
CD (P = 0.05)	15	14	15	0.25	0.24	0.23	851	781	763
Interaction : NS									

Table 6. Interaction effect of nitrogen and weed management practices on dry matter production (kg ha-1) at harvest of maize

Treatment	2019					2020					Pooled				
	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**
Unweeded check	3279	5631	9164	9264	6835	3113	5248	8857	8788	6502	3196	5440	9011	9026	6668
Hand weeding twice at 15 and 30 DAS	7994	13557	16540	15896	13497	7828	13173	16234	15490	13181	7911	13365	16387	15693	13339
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of topramezone @ 30 g/ha	7960	13384	16203	15416	13241	7794	13001	15897	14940	12908	7877	13193	16050	15178	13074
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of tembotrione @ 120 g/ha	7601	13059	16155	15229	13011	7435	12975	15779	14753	12736	7518	13017	15967	14991	12874
Application of parthenium water extract @ 15 l/ha twice at 15 and 30 DAS	4299	6940	10281	8679	7550	4433	6857	9775	8503	7392	4366	6899	10028	8591	7471
Application of sunflower water extract @ 15 l/ha twice at 15 and 30 DAS	4406	7033	10157	9171	7692	4390	6799	10001	8845	7509	4398	6916	10079	9008	7600
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of parthenium water extract @ 15 l/ha	4711	7444	10123	9184	7866	4545	7061	9817	8708	7533	4628	7253	9970	8946	7699
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of sunflower water extract @ 15 l/ha	4957	7772	10313	9241	8071	4791	7389	10006	8765	7738	4874	7581	10160	9003	7904
Brown manuring	7509	10883	13310	12992	11174	7025	10500	13004	12516	10761	7267	10692	13157	12754	10967
Mean	5857	9523	12472	11675		5706	9223	12152	11256		5782	9373	12312	11465	
	SEm ±		**CD (P = 0.05)**			**SEm ±**		**CD (P = 0.05)**			**SEm ±**		**CD (P = 0.05)**		
N	238.0		824			248.0		858			235.4		815		
W	301.3		851			276.5		781			270.2		763		
N at W	603.2		1703			573.1		1698			590.5		1701		
W at N	585.4		1930			604.4		1988			574.9		1892		

Table 7. Effect of nitrogen and weed management practices on kernel yield (kg/ha) of maize

Treatment	2019					2020					Pooled				
	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N	Soil test based fertilizer application	**Mean**
Unweeded check	23.8	41.5	60.8	51.2	44.3	16.0	38.3	52.7	50.3	39.3	19.9	39.9	56.8	50.8	41.8
Hand weeding twice at 15 and 30 DAS	56.9	95.1	139.2	106.4	99.4	49.6	92.9	123.9	104.1	92.6	53.3	94.0	131.6	105.3	96.0
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of topramezone @ 30 g/ha	56.3	90.5	129.5	107.0	95.8	46.2	82.8	111.9	102.7	85.9	51.3	86.7	120.7	104.9	90.9
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of tembotrione @ 120 g/ha	55.5	87.1	127.7	105.7	94.0	45.0	80.0	107.2	101.3	83.4	50.3	83.6	117.5	103.5	88.7

Application of parthenium water extract @ 15 l/ha twice at 15 and 30 DAS	28.3	54.4	66.2	63.8	53.2	22.5	52.1	66.3	57.3	49.6	25.4	53.3	66.3	60.6	51.4
Application of sunflower water extract @ 15 l/ha twice at 15 and 30 DAS	29.2	53.5	68.7	65.7	54.3	24.9	53.3	70.0	60.2	52.1	27.1	53.4	69.4	63.0	53.2
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of parthenium water extract @ 15 l/ha	32.0	63.4	70.3	66.4	58.0	28.3	55.1	70.7	61.3	53.9	30.2	59.3	70.5	63.9	55.9
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of sunflower water extract @ 15 l/ha	34.5	62.0	72.6	67.6	59.2	29.7	57.4	72.6	63.9	55.9	32.1	59.7	72.6	65.8	57.5
Brown manuring	44.0	75.6	95.7	94.6	77.5	35.8	73.1	97.0	83.1	72.3	39.9	74.4	96.4	88.9	74.9
Mean	40.1	69.2	92.3	80.9		33.1	65.0	85.8	76.0		36.6	67.1	89.1	78.5	
	SEm ±		CD (P = 0.05)			SEm ±		CD (P = 0.05)			SEm ±		CD (P = 0.05)		
N	2.32		8.0			2.63		8.9			2.41		8.6		
W	2.90		8.2			3.29		9.3			2.96		8.5		
N at W	6.45		18.1			6.58		18.6			6.67		18.9		
W at N	6.57		19.1			7.57		25.0			6.89		21.2		

Table 8. Effect of nitrogen and weed management practices on cob length (cm) of maize

Treatment	2019					2020					Pooled				
	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**
Unweeded check	9.3	12.0	13.5	13.2	12.0	8.9	11.3	13.3	12.0	11.4	9.1	11.7	13.4	12.6	11.7
Hand weeding twice at 15 and 30 DAS	14.9	17.1	21.7	18.8	18.1	14.0	17.0	21.3	18.3	17.7	14.5	17.1	21.5	18.6	17.9
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of topramezone @ 30 g/ha	14.4	17.0	21.6	18.9	18.0	13.9	16.5	21.1	18.9	17.6	14.2	16.8	21.4	18.9	17.8
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of tembotrione @ 120 g/ha	14.2	16.8	21.1	18.4	17.6	13.8	16.5	20.6	18.7	17.4	14.0	16.7	20.9	18.6	17.5
Application of parthenium water extract @ 15 l/ha twice at 15 and 30 DAS	10.5	12.9	15.2	14.0	13.2	10.0	13.4	14.2	13.9	12.9	10.3	13.2	14.7	14.0	13.0
Application of sunflower water extract @ 15 l/ha twice at 15 and 30 DAS	10.8	13.1	15.7	14.1	13.4	10.4	12.4	15.3	14.0	13.0	10.6	12.8	15.5	14.1	13.2
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of parthenium water extract @ 15 l/ha	10.9	13.5	15.0	14.3	13.4	10.7	13.3	14.9	13.7	13.2	10.8	13.4	15.0	14.0	13.3
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of sunflower water extract @ 15 l/ha	11.3	13.2	15.7	14.4	13.7	11.2	12.8	15.1	14.0	13.3	11.3	13.0	15.4	14.2	13.5

Brown manuring	13.6	16.0	17.7	17.0	16.1	12.8	15.8	17.4	16.6	15.7	13.2	15.9	17.6	16.8	15.9
Mean	12.2	14.6	17.5	15.9		11.7	14.3	17.0	15.6		12.0	14.5	17.2	15.7	
	SEm ±		CD (P = 0.05)			SEm ±		CD (P = 0.05)			SEm ±		CD (P = 0.05)		
N	0.35		1.2			0.31		1.1			0.33		1.1		
W	0.37		1.1			0.43		1.2			0.44		1.2		
N at W	0.75		2.1			0.87		2.3			0.87		2.5		
W at N	1.03		3.4			0.91		3.0			0.98		3.2		

Table 9. Effect of nitrogen and weed management practices on kernel yield (kg/ha) of maize

Treatment	**2019**					**2020**					**Pooled**				
	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based fertilizer application	**Mean**
Unweeded check	1042	2134	3775	3499	2612	966	1884	3426	3249	2381	1004	2009	3601	3374	2497
Hand weeding twice at 15 and 30 DAS	3287	6265	8050	7570	6293	3178	6099	7918	7404	6150	3232	6182	7984	7487	6221
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of topramezone @ 30 g/ha	3240	6157	7779	7321	6124	2998	5992	7646	7155	5948	3119	6074	7712	7238	6036
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of tembotrione @ 120 g/ha	2980	5824	7712	7231	5937	2738	5648	7446	7064	5724	2859	5736	7579	7148	5830
Application of parthenium water extract @ 15 l/ha twice at 15 and 30 DAS	1401	2766	4245	3703	3029	1242	2584	4179	3473	2869	1322	2675	4212	3588	2949
Application of sunflower water extract @ 15 l/ha twice at 15 and 30 DAS	1445	2827	4397	3931	3150	1270	2661	4264	3587	2945	1358	2744	4330	3759	3048
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of parthenium water extract @ 15 l/ha	1569	3066	4489	3931	3264	1394	2900	4322	3765	3095	1482	2983	4406	3848	3179
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of sunflower water extract @ 15 l/ha	1644	3217	4532	3972	3341	1468	3052	4365	3831	3179	1556	3135	4448	3902	3260
Brown manuring	2730	4741	6064	5735	4818	2564	4574	5898	5568	4651	2647	4658	5981	5651	4734
Mean	2149	4111	5671	5210		1980	3933	5496	5011		2064	4022	5584	5111	
	SEm ±		CD (P = 0.05)			SEm ±		CD (P = 0.05)			SEm ±		CD (P = 0.05)		
N	114.3		393			116.7		400			111.3		386		
W	141.2		397			146.3		413			139.7		337		
N at W	281.3		794			298.3		826			267.7		809		
W at N	340.7		826			346.2		857			334.1		846		

Table 10. Effect of nitrogen and weed management practices on stover yield (kg/ha) of maize

Treatment	**2019**					**2020**					**Pooled**				
	Control	Recommended dose of fertilize	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilize	Green seeker directed N application	Soil test based fertilizer application	**Mean**	Control	Recommended dose of fertilizer	Green seeker directed N application	Soil test based r fertilize application	**Mean**
Unweeded check	2018	3252	4843	4641	3689	1902	3216	4756	4415	3572	1960	3234	4800	4528	3630

Hand weeding twice at 15 and 30 DAS	4503	7050	8366	8150	7017	4253	6804	8286	7990	6833	4378	6927	8326	8070	6925
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of topramezone @ 30 g/ha	4501	6975	8215	7884	6894	4251	6762	7958	7724	6674	4376	6869	8087	7804	6784
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of tembotrione @ 120 g/ha	4372	6501	8178	7787	6710	4122	6321	7928	7627	6500	4247	6411	8053	7707	6605
Application of parthenium water extract @ 15 l/ha twice at 15 and 30 DAS	2668	3937	5471	4764	4210	2418	3790	5351	4571	4033	2543	3864	5411	4668	4121
Application of sunflower water extract @ 15 l/ha twice at 15 and 30 DAS	2728	4014	5490	5029	4315	2478	3867	5470	4719	4134	2603	3941	5480	4874	4224
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of parthenium water extract @ 15 l/ha	2923	4370	5543	5041	4469	2673	4123	5363	4848	4252	2798	4247	5453	4945	4361
PE application of atrazine @ 1.0 kg/ha *fb* PoE application of sunflower water extract @ 15 l/ha	2980	4537	5554	5058	4532	2762	4290	5301	4998	4338	2871	4414	5428	5028	4435
Brown manuring	4552	5894	7027	6713	6047	4302	5747	6974	6553	5894	4427	5821	7001	6633	5970
Mean	3472	5170	6521	6119		3240	4991	6376	5938		3356	5081	6449	6028	
	SEm ±		CD (P = 0.05)			SEm ±		CD (P = 0.05)			SEm ±		CD (P = 0.05)		
N	106.2		367			111.9		384			105.8		348		
W	176.2		497			170.5		481			156.2		441		
N at W	322		898			334		913			303		881		
W at N	352		995			341		962			315		915		

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