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Report

Evaluation of Weed Management Practices in Maize (*Zea mays*) at Metu, Ethiopia

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Abstract

A field experiment was conducted at Metu Agricultural sub – centre on station in 2015 and 2016 cropping seasons to evaluate the effectiveness and economic feasibility of weed management methods on maize grain yield at Metu area. BH 661 at 25 kg/ha used as seed source. The experiment comprised of nine treatments laid out in randomized complete block design (RCBD) with three replications. The result revealed that the highest average grain yield 62.8 q/ha was obtained from Integrity EC 668g/l 1.0 liter with two supplementary hand weeding followed by 61.6 q/ha from Integrity EC 668g/l 1 liter with one hand weeding. Similarly, the minimum above ground wee dry biomass mean 0.07q/ha, 1.5 q/ha obtained from three hand weeding at 30, 60 and 90 days after planting and Integrity EC 668g/l 1.0 liter with two supplementary hand weeding respectively. Consequently highest weed control efficiency 99.93% and 98.5%obtained from the same treatment. In economic feasibility aspect the highest net benefit Accordingly the highest net benefit 61296.4 ETB ha^{-1} was obtained from Integrity EC 668g/l at 1.0 L/ha + two time supplementary hand weeding with 3042.86 MRR% followed by 60146.2 ETB ha^{-1} net benefit with 5661.90% MRR obtained from Integrity EC 668g/l at 1 l/ha + one times supplementary hand weeding whereas the minimum net benefit 50551.2 ETB ha^{-1} and 53224.2 ETB ha^{-1} obtained from one hand weeding at 30 & 454 days after planting respectively. Therefore, Integrity EC 668g/l at 1 l/ha + two times supplementary hand weeding and Integrity EC 668g/l at 1 l/ha + one time supplementary hand weeding treatment consecutively more profitable weed management practices to control weeds in maize and there by improve crop production up to 56.94% than other treatments and can be recommended for maize production at Metu area.

Keywords

Economic Analysis, Hand Weeding, Integrity Herbicide, Weed Free, Metu

1. Introduction

Maize (*Zea mays* L) is one of the most important cereal crops in the world agricultural economy both as food for man and feed for animals. In Africa, Ethiopia is the third largest maize producer next to Nigeria and Egypt [1]. It exceeds all other cereal crops in the country in terms of annual production and productivity which ranks second most cultivated crop after teff in area coverage and first in total production in Ethiopia [2, 3]. It is well known heavy

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feeder for both nutrients and soil moisture due to its high productivity.

The relatively high yield obtained per hectare and the favorable growing conditions of Southwest Ethiopia have led to a trend of increasing maize production in the Country. However, maize production is constrained by several important biotic and a biotic factors among which weed is the major. Weed infestation is a very serious and less attended issue in the country. Among cereal crops, it infested with variety of weeds and subjected to heavy weed competition, which causes 58.1% yield losses [4]. According to Getahun et al. maize grain yield lose 87.5% causes due to weed competition under Asosa condition [5]. Weeds are one of the major factors reducing crop yield, deteriorate quality of crops and reduce farmers' income. Kebede reported that weed infested maize field causes up 40% yield loses in Ethiopia [6]. The heavy rainfall of Southwest part of the country encourages rapid and abundant growth of weeds and consequently, all agricultural crops are heavily infested with weeds. Farmers in the country are aware of weed problem in their fields but often they cannot cope-up with heavy weed infestation during the peak-period of agricultural activities because of labor shortage, hence, most of their fields are weeded late or left un-weeded. Such inadequate weed management considered as the main factor for low grain yield of maize. Maize is very susceptible to competition from weeds especially in the early stages of growth. Therefore, efficient control at pre- and early post-emergence stages is essential. Hence, once it reaches approximately 0.5 m in height, weed control no longer affects yield [7]. Effective weed control methods in maize increased grain yield 77% - 96.7% than weed check [8]. Maize is the major growing crop of southwest Ethiopia and as a result ample weed control including herbicide is available in the study area. Nevertheless, the economic feasibility of integration of cultural and herbicide weed control methods was not yet evaluated. Hence this experiment was conducted with the objective to evaluate integration effectiveness and economic feasibility of weed management methods on weed control performance and maize production & productivity.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted for consecutive 2015 and 2016 main cropping season at Metu on station in Southwest Ethiopia. Metu sub centre located at 541.5km from Addis Ababa and located at an altitude of 1550 m.a.s.l with a mean annual rainfall of 1810.6 mm. The mean maximum and minimum temperatures of the centre are 28.0°Cand 12.2°C respectively.

2.2. Treatments and Experimental Design

The experiment was laid out in Randomized Block Design with three replications and comprised of nine treatments for compression of time of hand weeding and frequency in combination with the pre-emergence herbicide Integrity EC 668g/l (Table 1). BH 661 maize variety was used as seed source on 7.5m x 5.6m ($42m^2$) plot size. 1.5m and 1m space were be used between block and plot respectively. The crop was spaced at 75 cm × 25 cm spacing between rows and plant respectively. Two maize seeds were planted per hill and then thinned to one plant per hill after good establishment of seedlings so as to maintain a single healthy plant per hill.

The herbicide Integrity EC 668g/l was sprayed at a rate of 1.0 l/ha. In 150 l/ha of water volume as pre emergence at third day after maize planting using knapsack sprayer fitted with yellow nozzle with swath width of 2 meters. NP fertilizer rate of 92/69 kg/ha was applied as per recommendation. Half of N and the whole amount of P was applied at the time of sowing. The remaining half of N was applied at knee high growth of the crop. Hand weeding was done both by hand pulling and hoeing.

Table 1. *Treatment Combination.*

Treatment	Descriptions
T1	One hand weeding at 30 days after planting
T2	One hand weeding at 45 days after planting
T3	Two hand weeding at 30 and 60 days after plating
T4	Three hand weeding at 30, 60 and 90 days after planting
T5	Pre -emergence Integrity EC 668g/l1.0 l/ha
T6	Pre- emergence Integrity EC 668g/l1.0 l/ha + one supplementary hand weeding at 60 DAP
T7	Pre - emergence Integrity EC 668g/l 1.0 l/ha + two supplementary hand weeding at 60 and 90 DAP
T8	Weed free (four times hand weeding at 30, 60, 90 and 120 days after planting)

Treatment	Descriptions
T9	Weedy Control

DAP = days after planting, ha= hector

2.3. Collected Data

Weeds were recorded identified and categorized into broadleaved and grasses by visual observation and using weed identification guide [9]. Weed population was also counted with the help of quadrate thrown randomly at three places in each plot every time beforehand weeding practice applied. Total above ground weed dry weight was recorded from harvested weed population at fifteen day before harvesting within quadrate thrown above ground. The harvested weeds were dried in sun light till constant weight and subsequently the dry weight was measured and converted in to kg/ha. Weed control efficiency (WCE) is calculate to determine the variation in the dry matter weight accumulated due to competition with the maize crop of the treated plot as compare to the weedy check and the relative percent grain yield loss (YL) was calculated using formulas described below [10, 11].

$$\text{WCE} = \frac{\text{WDC}-\text{WDT}}{\text{WDC}} \times 100$$

Where WDC= weed dry mass from the control plot (untreated), WDT= weed dry matter from treated plot.

$$\text{Relative Yield Loss (YL) (\%)} = \frac{Y1-Y2}{Y1} * 100$$

Where YL= Yield loss, Y1 and Y2 represent yield of the weed free and other treatments respectively.

Plant height (cm), Number of cob per plant and thousand kernel weights (g) adjusted at 12.5% moisture content were measured from five randomly selected plants in harvest rows of each plot. Stand count and field weight (kg) per plot were taken from harvestable rows excluding one row on each side of the plots to avoid border effect at harvesting.

Gross average maize grain yield (t/ha) (AvY): An average yield of each treatment converted in hectare base. Adjusted yield (AjY): Average yield adjusted downward by 10% to reflect the difference between the experimental yield and yield of farmers thus: jY (t/ha) = AvY × (1-0.1). Percentage yield advantage (%) and yield loss were calculated by the formulas suggested below.

$$\text{Adjusted grain yield (kg ha}^{-1}) = \frac{\text{Actual yield x 100 - M}}{100-\text{D}}$$

Where, M = the measured moisture content of maize grain and D = designated moisture content (12.5%).

$$\text{Percentage yield advantage (PYA\%)} = \frac{\text{Yt} - \text{Yc}}{\text{Yt}} \times 100$$

Where, Yt is yield in any treatment and Yc is yield in weedy check (control) plot. Yield loss of the crop due to weed infestation was assessed with the manipulation of the yield obtained from maximum protected plot with yield of lower treatments.

2.4. Statistical Analysis

Data were subjected to the analysis of variance. Mean separation was conducted for significant treatment means using Least Significance Differences (LSD) at 5% probability level using SAS computer software 9.4 version.

2.5. Economic Analysis

Partial budget analysis was performed to investigate the economic feasibility of the treatments following the method used by CIMMYT to assess the biological productivity and economic feasibility of the herbicides with compare hand weeding practice in suppressing weed infestation and increasing maize productivity [12]. Adjusted yield (AjY): Average yield adjusted downward by 10% to reflect the difference between the experimental yield and yield of farmers thus: jY (t/ha) = AvY × (1-0.1). Gross field benefit (GFB) (ETB/ha): Computed by multiplying field/farm gate price (quintal/ha) by adjusted yield thus: GFB = AjY × field/farm gate price for the crop. Total variable cost of herbicide and hand weeding used for the experiment. The costs of other inputs and production practices such as fertilizer, seed labor cost for land preparation, planting and harvesting was considered to remain the same or will be insignificant among treatments. Net benefit (NB) (ETB/ha): Calculated by subtracting the total costs from gross field benefits for each treatment thus: NB = GFB - total cost. This analysis was done after collecting all data using the prevailing market prices for herbicide and labor cost for hand weeding practice of the area to identify the most economical feasible treatments used in weed management methods. All costs and benefits were calculated on a per hectare basis in Ethiopian Birr (ETB).

3. Result and Discussion

3.1. Weed Species Composition

The major weed species recorded at experimental field

were presented in Table 2. Experimental field was infested with eleven (11) weed species belonging to six (6) families. Among total weed species 63.64% were broad leaved whereas 36.36% were grasses (Table 2). In terms of their life cycle 54.55% were annual broadleaved weeds and 45.45% were perennial grass weeds. These indicate that species rich weed community in the experimental field.

Annual broad leaved weeds such as *Guziotia scabra, Bidens polychyma, Commelina benghalensis* and *Nicadraphysaloides* were continuously growing at the field during the growth period. These weeds are the major competitors of maize and can result in considerable yield loss in maize unless they are adequately controlled from critical time of crop weed competition until the crop canopy completely cover the soil to inhibit their robust growth. These weeds were observed growing tall above the maize plants in the weedy control totally smothering the crop. This result is in lines with Mehmeti et al who reported that different weeds species infested a single experimental site [13].

Table 2. *Major weed species recorded at the experimental field and the surrounding.*

Botanical name	Family	Life cycle	Economic importance
Gyzotia scabra	Asteraceae	Annual	noxious
Commelina benghalencies	Commelinaceae	Perennial	noxious
Digitaria abyssinica	poaceae	Perennial	noxious
Nicandra physaloides	solanaceae	Annual	noxious
Bidens pilosa	Asteraceae	Annual	Noxious
Ageratum conyzoides	Asteraceae	Annual	Noxious
Cyperus esculentus L.	Cyperaceae	Perennial	Noxious
Cyperus rotundus L.	Cyperaceae	Perennial	Noxious
Galinsoga parviflora	Asteraceae	Annual	important
Cynodon dactylon L.	Poaceae	Annual	Important
Polygonum nepalenseMeisn	Polygonaceae	Annual	important

3.2. Maize Stand Count at Harvest

The present analyzed data revealed that significant differences among treatments on crop stand count at harvesting (Table 3). The maximum mean stand count (121.4) followed by 120.2 and 106.2 were recorded from the plots received Integrity EC 668g/l 1.0 /ha + two hand weeding Integrity EC 668g/l 1.0 l/ha + one hand weeding and Integrity EC 668g/l 1 Liter/ha respectively. While the minimum stand count (59.7) recorded from weedy control plot. This indicate that using pre-emergence herbicide reduces crops physical damage because of it restricted the iterance of the field at early growth stage.

3.3. Plant Height (m)

In accordance with plant height, there was no significant variation among treatments. However, the highest plant height mean value (3.01m) recorded from the plot treated with Integrity EC 668g/l+ two hand weeding while the shortest mean plant height (2.60m) recorded from the plot received one hand weeding at 30 days after planting.

3.4. Weed Dry Weight (kg/ha)

Weed dry weight mean significantly influenced by weed management methods. As the result showed the maximum weed dry biomass mean obtained from plots received minimum weed management practice and weedy control. The highest above ground weed biomass 102.8 quintal ha^{-1} followed by 26.2 quintal ha^{-1} were obtained from weedy control and Integrity EC 668g/l 1 L ha^{-1}respectively while the minimum above ground dry biomass mean obtained from weed free and three hand weeding at 30, 60 and 90 days after planting. This result agrees Abdullahi et al who reported that lowest weed dry weight in maize was obtained from plots treated with pre-emergence herbicide + one hand weeding followed by weed free plot compared with other treatment [16].

Dry biomass above ground of weed was significantly reduced when Integrity EC 668g/l herbicide combined with one and two supplemented with hand weeding as compared with Integrity EC 668g/l herbicide alone. This might be be-

cause a weed free maize during the early establishment and growth period could well competes with weeds at later stages of growth and development of maize without yield being affected. This result in lines with Temesgen et al, reported that the highest weed biomass was recorded in the weedy check treatment followed by herbicide treatment alone [14].

3.5. Weed Control Efficiency (WCE %)

The study result showed that weed control efficiency significantly affected by weed control methods in maize. The highest weed control efficiency (100%, 99.93%, 98.5% and 91.2%) were obtained from weed free plot, three hand weeding and Integrity EC 668g/l 1.0 l/ha + two hand weeding respectively (Table 4). This result indicated that pre-emergence herbicide with supplementary hand weeding effectively suppress germination of major weeds in maize experimental field at early growth stage resulted in reducing weed density and weed dry weight next to weed free and tree times hand weeding. Similarly, Tesfay et al. reported that maximum hand weeding plus hoeing is effective weed control methods and improve yields in maize in maize production. However, due to the labor shortage herbicide is the most effective measures effectively control weeds in maize as compared with other treatments [15].

3.6. Grain Yield (Q/ha)

All weed management methods improved maize grain yield compared with weedy control. Accordingly the highest yield 62.8 quintal ha^{-1} followed by 61.60 quintal $ha^{-1}$and 60.1 quintal ha^{-1}obtained from, Integrity EC 668g/l 1.0 l/ha herbicide + two hand weeding, Integrity EC 668g/l 1.0 l/ha herbicide + one hand weeding and three hand weeding respectively next to weed free. However, no statistical different observed among these treatments. The highest grain yield 64. q/ha^{-1} obtained from weed free plot while the lowest grain yield 27.6 quintal ha^{-1} was obtained from weedy control which is statistically different. The lowest grain yield in these treatments might be due to competition for resources as a result of high weed density and weed dry weight (Table 3).

This result similar with of Abdullahi et al. study result who stated that different weed control methods significantly enhanced yield and yield components of maize as compared to weedy check [16]. Moreover, Integrity EC 668g/l pre-emergence herbicide +one & two supplementary hand weeding and three times hand weeding gave significantly highest grain yield compared with one hand weeding at different time & Integrity EC 668g/l herbicide alone. This might be due to application of pre- emergence herbicide till later hand weeding practices and hand weeding practice applied from early growth stage reduced competition from weeds which could have resulted in initial advantage in favor of the crop. This finding is similarly, with Dawit et al who reported that combined use of pre-emergence herbicides with hand weeding at 35 days after sowing increased the yield of common bean [17].

3.7. Relative Yield Loss (Weed Index) (%)

The present data indicated that the relative yield loss in maize grain yield due the presence of weeds ranged from 2.03 to 56.94%. Uninterrupted weed growth & the lowest treatment resulted in 56.94, 20.36 and 16.15% yield loss over weed free and other treatments like: weedy control, One hand weeding at 30 days after sowing and One hand weeding at 45 days after sowing respectively (Table 4). Similarly the maximum percent yield advantage revealed from the plots received maximum treatment and herbicide integrated with hand weeding. In general the maize grain yield loss due to weed competition under Metu condition is 56.94%.

Table 3. *Mean effect of weed management methods on maize yield components over season.*

Treatment	Stand count at harvest	Plant height (cm)	Weed dry wt (q/ha)	WCE (%)
One hand weeding at 30 days after sowing	98.4^{bc}	260.2	10.8^{ab}	89.5
One hand weeding 45 days after sowing	97.9^{bc}	269.7	10.5^{ab}	89.8
Two hand weeding at 30 and 60 days after sowing	92.7^{c}	280.0	10.3^{ab}	89.9
Three hand weeding at 30, 60 and 90 days after sowing	96.5^{bc}	304.5	0.07^{a}	99.93
Integrity EC 668g/l at 1.0 l/ha	106.2^{b}	286.7	23.2bc	77.43
Integrity EC 668g/l at 1.0 l/ha + one hand weeding	120.2^{a}	270.6	9.1^{ab}	91.2
Integrity EC 668g/l 1.0 l/ha + two hand weeding	121.4^{a}	301.1	1.5^{a}	98.5
Weed free control	101.0^{b}	286.8	0.0^{a}	100.0
Weedy control	59.7^{d}	276.3	102.8^{d}	0.0

Treatment	Stand count at harvest	Plant height (cm)	Weed dry wt (q/ha)	WCE (%)
LSD (5%)	12.6	NS	23.8	
CV (%)	12.7	19.5	17.3	

WCE= weed control efficiency, wt= weight

Table 4. Effect of weed management methods on maize grain yield over season.

Treatment	Grain Yield Q/ha			Relative yield Loss (%)	(%) Yield advantage
	2015 Year	2016 Year	Mean		
One hand weeding at 30 days after sowing	48.5b	53.6ab	51.05	20.36	45.94
One hand weeding 45 days after sowing	55.0ab	52.5ab	53.75	16.15	48.65
Two hand weeding at 30 and 60 days after sowing	58.2ab	57.9ab	58.05	9.44	52.45
Three hand weeding at 30, 60 and 90 days after sowing	59.5ab	60.6ab	60.05	6.32	54.04
Integrity EC 668g/l at 1.0 l/ha	53.9ab	64.8ab	59.35	7.41	53.50
Integrity EC 668g/l at 1.0 l/ha + one hand weeding	59.6ab	63.6ab	61.6	3.90	55.20
Integrity EC 668g/l 1.0 l/ha + two hand weeding	61.4a	64.2ab	62.8	2.03	56.05
Weed free	60.2a	68.0a	64.1	0	56.94
Weedy control	29.3c	25.90c	27.6	56.94	--
LSD (5%)	11.3	19.9	-		
CV (%)	12.7	15.6	-		

3.8. Economic Analysis

This economic analysis was performed based on the average yield of each treatment over seasons using the Partial budget technique [12, 18]. Yield and economic data were collected to compare the economic advantage of each weed management methods in maize production. The cost for land preparation, maize planting, fertilizer, fertilizer application and harvesting were uniform for all treatments. Accordingly, The prescribed prices of Herbicide (Integrity EC 668g/l = 800 birr liter $^{-1}$) based on stock market price of chemical company in May 2015 and 2016.

Moreover, the average maize grain sale price at open market at Metu area in, 2015 and 2016 was (11.00 ETH Birr kg $^{-1}$). Daily Labor cost for hand weeding and hoeing was 50.00/ man and the norm were 30 men per day ha^{-1}. Accordingly the highest net benefit 61296.4ETB ha^{-1} was obtained from Integrity EC 668g/l at 1.0 l/ha+ two time supplementary hand weeding with 3042.86 MRR% followed by 60146.2ETB ha^{-1}net benefit with5661.90% MRR obtained from Integrity EC 668g/l at 1.0 l/ha + one times supplementary hand weeding whereas the minimum benefit 50551.2 ETB ha^{-1}and 53224.2 ETB ha^{-1}obtained from one hand weeding at 30 & 454 days after planting respectively (Table 5). The highest gross field benefit obtained from weed free treatment than in the other treatments was due to higher yield. Furthermore, weed competition attributed low yield which resulted the low net benefit. From the economic point of view, the study result suggested that Integrity EC 668g/l at 1.0 l/ha + two time supplementary hand weeding treatment is the more profitable than other treatments. This finding in lines with Tadele et al who reported intensive farming system integrated with weed management methods (two-time hand weeding at 2 and 5 weeks after crop emergence and S-metholachlor at 1.0 kg ha^{-2} + one hand weeding and hoeing at 4-5 weeks after crop emergence are increase the chickpea yield [19].

Table 5. Partial budget analysis for weed management practices during 2015 &2016 cropping season.

Parameters	Treatments								
	1HW at 30 DAP	1HW at 45 DAP	2HW at 30 & 60DAP	3HW at 30, 60 & 90 DAP	Weed free	Integrity EC 668g/l at 1.0 l/ha	Integrity EC 668g/l at 1.0 l/ha + 1HW	Integrity EC 668g/l at 1.0 l/ha + 2HW	Weedy control
Gross farm benefits									
Average yield (q/ha)	51.1	53.8	58.1	60.1	64.1	59.4	61.6	62.8	27.6
Adjusted yield (q/ha)	45.99	45.99	52.29	52.29	57.69	53.46	55.44	56.52	24.84
GF B (EB ha^{-1})	50589	53262	57519	59499	63459	58806	60984	62172	27324
Weed management input cost									
Daily labor cost	37.80	37.80	75.60	113.40	151.2	-	37.80	75.60	-
Herbicide cost (ETB L^{-1})	-	-	-	-	-	800.00	800.00	800.00	-
TVC (ETB ha^{-1})	37.80	37.80	75.60	113.40	151.2	800.00	837.80	875.60	-
Net benefit (ETB ha^{-1})	50551.2	53224.2	57443.4	59385.6	63307.8	58006	60146.2	61296.4	
Benefit: cost ratio (B:C)	1337.33	1408.05	759.83	523.68	418.70	72.51	71.79	70.01	
MRR (%)			111.62	5138.1	10376.19	D	5661.90	3042.86	

1HW= one hand weeding, 2HW= two hand weeding, DAP = days after planting, GFB= Gross field benefit, TVC= Total variable cost, MRR= Marginal Rate of Return, ETB= Ethiopian Birr

4. Conclusion and Recommendation

In the present study different weed management practices had showed significant effect on controlling major weeds in maize experimental field and improving maize productivity. The highest weed control efficiency (100%, 99.93%, 98.5% and 91.2%) were obtained from weed free plot, three hand weeding and Integrity EC 668g/l 1.0 l/ha + two hand weeding respectively compared with other treatments. Similarly, The highest average grain yield 62.81q/ha^{-1}Integrity EC 668g/l 1.0 l/ha herbicide + two hand weeding at 60 & 90 days after planting followed61.6q/ha^{-1} Integrity EC 668g/l 1.0 l/ha herbicide + one hand weeding at 60 days after planting. Whereas, the lowest grain yield 27.6 kg ha^{-1} was obtained from weedy control. Moreover, in this study grain yield loss due to weed competition under Metu condition 56.94% is quantified. In terms of economic analysis the study indicated that the highest net benefit 61296.4 ETB ha^{-1} was obtained from Integrity EC 668g/l at 1.0 l/ha+ two time supplementary hand weeding with 3042.86 MRR% followed by 60146.2ETB ha^{-1}net benefit with5661.90% MRR obtained from Integrity EC 668g/l at 1 L/ha + one time supplementary hand weeding whereas the minimum net benefit 50551.2 ETB ha^{-1} and 53224.2ETB ha^{-1}obtained from one hand weeding at 30 & 454 days after planting respectively Therefore, on the basis of present study result, Integrity EC 668g/l at 1 L/ha+ two times supplementary hand weeding and Integrity EC 668g/l at 1.0 l/ha + one time supplementary hand weeding treatment is more profitable weed management practice to control weeds in maize and there by improve yield production up to 56.94% than weedy control and can be recommended for Metu area.

Abbreviations

AjY: Average Adjusted Yield
CSA: Central Statistical Agency
DAP: Days After Planting
EC: Emulsifiable Concentrates
ETB: Ethiopian Birr
FAO: Food and Agricultural Organization
GFB: Gross Field Benefit
HW: Hand Weeding
Kg: Kilogram
MRR: Marginal Rate of Return
NP: Nitrogen, Phosphorus Fertilizer
RCBD: Randomized Complete Block Design
TVC: Total Variable Cost
Wt: Weight

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Conflicts of Interest

The authors declare no conflict of interest.

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