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Effect of Post Emergence Herbicides and their Mixtures on Weed Dynamics, Yield Components and Yield of Rice (*Oryza Sativa* L.), At Guraferda Woreda, South Western Ethiopia

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Abstract- Weeds are the principal limiting biological factor in national rice production, with losses that vary from region to region, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers. Therefore, the experiment was conducted in Bench Maji Zone at Guraferda Woreda, during the 2017 main cropping season to investigate the effect of Bispyribac-sodium 10% SC, and 2, 4-D amine salt on weeds growth, yield components and yield of rice and to investigate the possibilities of supplementing low doses of herbicides with hand weeding for effective and cost effective weed management. There were 12 treatments comprising: Bispyribac-sodium 10% SC (20 g ha-1 ,25 g ha-1,30 g ha-1), 2, 4-D amine salt (0.75 L ha-1,1.0 L ha-1 , 1.25 L ha-1), Bispyribacsodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha-1, Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha- 1, Bispyribac-sodium (20 g ha-1) + hand weeding and hoeing at 35DAE , 2, 4-D amine salt (0.75 L ha-1) + hand weeding and hoeing at 35DAE, Weed free and Weedy checks. The design of the experiment was RCBD with three replications. The majority of the weeds in the experimental fields were broadleaved, grassy and sedges.

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Abstract- Weeds are the principal limiting biological factor in national rice production, with losses that vary from region to region, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers. Therefore, the experiment was conducted in Bench Maji Zone at Guraferda Woreda, during the 2017 main cropping season to investigate the effect of Bispyribac-sodium 10% SC, and 2, 4-D amine salt on weeds growth, yield components and yield of rice and to investigate the possibilities of supplementing low doses of herbicides with hand weeding for effective and cost effective weed management. There were 12 treatments comprising: Bispyribac-sodium 10% SC (20 g ha^{-1} ,25 g ha^{-1},30 g ha^{-1}), 2, 4-D amine salt (0.75 L ha^{-1},1.0 L ha^{-1} , 1.25 L ha^{-1}), Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}, Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}, Bispyribac-sodium (20 g ha^{-1}) + hand weeding and hoeing at 35DAE , 2, 4-D amine salt (0.75 L ha^{-1}) + hand weeding and hoeing at 35DAE, Weed free and Weedy checks. The design of the experiment was RCBD with three replications. The majority of the weeds in the experimental fields were broadleaved, grassy and sedges. The influence of herbicides on weed density, weed dry biomass, weed control efficiency and weed index were clearly noticeable at harvest. The uppermost weed control efficiency 86.7% was noted from 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE which was in parity with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE. Bispyribac-sodium 10% SC 25 g ha^{-1} was effective in reducing weed index (18.77%). Suggestively lower number of tiller per plant, panicle length per plant and thousand seed weight was recorded with weedy check. The weed free check treatment recorded 43.76% higher yield over weedy check. Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE gave the highest harvest index (45.13%). The highest yield loss 62.44% was recorded in weedy check. The maximum net benefits were acquired with the application of Bispyribac-sodium 10% SC 25 g ha^{-1}, followed by 2, 4-D amine salt 1.0 L kg ha^{-1}. If low-cost and plenty labour are available Bispyribac-sodium 10% SC 20 g ha^{-1} + hand weeding and hoeing at 35 DAE should be done. With the availability of herbicides, Bispyribac-sodium 10% SC 25 g ha^{-1} followed by 2, 4-D amine salt 1.0 L kg ha^{-1} can be used to prevent the yield loss and to obtain maximum benefits from rice.

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I. Introduction

Rice (*Oryza sativa* L.), is the staple food of over half world's population and in Asia 1.3 billion and four hundreds of millions of people in Africa and Latin America depend on it for their diet [1]. Out of 472.39 million tonnes of Rice production in the world, 85 per cent is used for human consumption. Globally rice is cultivated in an area of 157.8 million hectare with a production of 491.3 million tonnes (2016-2017) [1]. Rice is a recent crop introduced to the Ethiopian farming systems and the cultivation of the crop has begun at Amara Region and Gambella plains in the early 1970's [2]; [3]; [4]. It is considered to be a highly productive crop next to maize in the country [5] and is an important market oriented crop. The introduction and expansion of rice production in suitable agro ecologies, therefore, could be an option to achieve food security and self-sufficiency. The country has immense potentials for growing the crop. According to ministry of agriculture and rural development report [6], the potential area for rice production in Ethiopia is estimated to be about thirty million hectares. Cereals specifically rice the one in which, the government has also recognized it as a millennium crop in light of ensuring food security in Ethiopia. It has also given especial focus to Agriculture in the poverty reduction strategy [7].

However weeds grow profusely in the rice fields and reduce crop yields drastically. Nowadays, weeds are considered as major biological constraints that reduces the potentiality of rice [8]; [9]. The risk due to weeds is lower in rice since the age old plants are transplanted so that the competition from the weeds is lower [10]. De to weed competition during the crop production the decrease in the yield was estimated to about 16 - 86 % [11].

Among different weed management methods, hand weeding is labourious, costlier and time consuming. Hand weeding is the predominant weed control practice on smallholder farms [12]. This method had been the oldest method of weed control which consists of hand pulling, hand slashing and hoeing of weeds. It is the major weed control method used in cereals production, but it is labor intensive and slow as compared to other manual weeding operations. It is usually delayed until the weeds are tall enough to be firmly held in the hand [13]. Smallholder farmers spend 50-70% of their total labour time in hand weeding [14]. On top of this, 69% of farmers' children between the ages of 5-14 are forced to leave school and are involved in the agricultural sector, especially at peak period of weeding [15].

Chemical control is a better alternative mechanism to manual weeding because it is cheaper, faster and gives better weed control [14]. The inability to control weeds by hand, lack of labour, and the drudgery involved in weeding in wet and or dry conditions will encourage and increasingly justify the use of herbicides [16]. Herbicide use would also improve the lives of farmers as it is devoid of farmer's engagement in such tedious task which may result in lifelong back deformities. By reducing the labour requirement for weed control, herbicide use could allow additional resources to be invested in food crops to the benefit of food security [17]. Studies showed that herbicides resulted in 97% greater wheat yield in comparison to the farmer practice of one hand weeding in Ethiopia [18]. Chemical control gave 38-55% higher crop yields, and had a 28-50% lower cost than farmer control methods [14].

As described above, weeds can be controlled by different methods. Even though, there exist different mechanisms of weed management, they vary in their efficiency of controlling weeds. Therefore, research has to be conducted to increase the efficiency of these methods and to decrease their hazardous effects. Now a day, there is large scale expansion of crops production in Ethiopia. This necessitates the use of herbicide due to shortage of labour and high labour cost during the peak periods.

Integrating herbicides with other weed management methods is an option for better weed control. IWM does not preclude herbicide use, it includes their judicious use along with other agronomic methods that help crops to compete with weeds and reduce weed seed production. IWM involves using an agronomical approach to minimize the overall impact of weeds and, indeed, maximize the benefits. The use of a single herbicide may result in shifting the weed flora in favor of the species that are not controlled, thus may increase the problem in the future. Therefore, herbicide combination is applied to broaden the spectrum of weeds controlled and sometimes the combinations can give spectacularly good control at doses considerably below those normally applied in single application. It may be additive or synergistic or prevent rapid detoxification of herbicide and are safer to crops and the user [14].

Consequently, information on herbicidal weed management practices in rice is limited in Southern Ethiopia in general and in Bench Maji Zone in particular. Therefore, the research was conducted to develop efficient, economical and herbicidal weed management practices for rice. The specific objectives were:

- To find out the effect of Bispyribac-sodium 10% SC, and 2, 4-D amine salt on weeds, and growth, yield components and yield of rice.
- To investigate the possibilities of supplementing low doses of herbicides with hand weeding for effective weed control.

II. Materials And Methods

a) *Description of Study Area*

The experiment was conducted in Southern Nations Nationalities Peoples Region, Ethiopia during the 2017 main cropping *'Meher'* season, in Bench Maji Zone at *Guraferda Woreda* research site.

b) *Experimental Materials*

New Rice for Africa (NERICA- 4) was used for this experiment. The key features of the new varieties, panicle can hold up to 400 grains compared to the 75-100 grains of its African parents, with an increase in yield from 1 to 2.5 t/ha which can increase to 5 t/ha with fertilizer use. It also matures 30-50 days earlier than traditional varieties. The adoption and cultivation of new rice varieties are increasing faster than any other food crops in many African countries [19].

Table 1: Description of herbicides used in the experiment

	Common name	Trade name	Chemical name
1	2,4-D Amine Salt	Power 860 SL	2,4-Dichlorophenoxyacetic acid
2	Bispyribac-sodium 10% SC	Pride 100 SC	Sodium 2,6-bis[(4,6-dimethoxy-2-pyrimidinyl)oxy]benzoate

c) *Treatments and Experimental Design*

The experiment was consisting of 12 treatments:

T1= Bispyribac-sodium 10% SC (20 g ha^{-1}) (Postemergence)

T2= Bispyribac-sodium 10% SC (25 g ha^{-1}) (Postemergence)

T3= Bispyribac-sodium 10% SC (30 g ha^{-1}) (Postemergence)

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T4= 2, 4-D amine salt (0.75 L ha^{-1}) (Postemergence)
T5= 2, 4-D amine salt (1.0 L kg ha^{-1}) (Postemergence)
T6= 2, 4-D amine salt (1.25 L ha^{-1}) (Postemergence)
T7= Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1} (Postemergence)
T8= Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1} (Postemergence)
T9= Bispyribac-sodium (20 g ha^{-1}) + hand weeding and hoeing at four- five weeks after crop emergence
T10= 2, 4-D amine salt (0.75 L ha^{-1}) + hand weeding and hoeing at four- five weeks after crop emergence
T11= Weed free check
T12= Weedy check

The design of the experiment was randomized complete block design (RCBD) with three replications. The plot sizes were 3 m X 2.4m. The distance between adjacent replication and plots were 1 and 0.5 meter respectively. The plot is consisting of 12 rows and 16 plants per rows spacing of 25cm x 15cm. The outer most two rows from each side of a plot and two plants on both ends of each row were considered as border and not be included for recording the observations. Thus, the net plot sizes were 2 m x 1.8m (3.6m^2).

d) Experimental Procedure

The experimental field was prepared following the conventional tillage practice before sowing the crop. In accordance with the specifications of the design, a field layout was prepared. The sizes of each experimental plot were 3 m x 2.4 m (7.2 m^2). The blocks were separated by 1m wide open spaces and the plots within a block were 0.5m apart from each other. Next to lay out the plots were leveled manually. Each treatment was assigned randomly to the experimental plots within a block. The rice NERICA-4 variety, it were planted on June 30/06/ 2017 with a spacing of 25 cm between rows and 15 cm between plants. There were 12 rows in each plot and 16 plants in each row. The herbicides were applied as the treatment in the assigned plots post emergence at tillering stage of rice. The amount of herbicides as per the treatment was calculated and measured using sensitive digital balance and measuring cylinder. Herbicide spray volume with water as carrier were 400-500 l /ha. Spraying was done with manually operated Knapsack sprayer (15 L capacity) using flat-fan nozzle. The spraying was done using a Knapsack sprayer. Hand weeding (hand weeding and hoeing) were done in the assigned plots as per the treatment. Harvesting was done, when the panicle and leaves were turned yellow. The harvested produce was sun dried for 3-5 days. Threshing and winnowing were done simultaneously and manually.

e) Data to be collected

i. *Data collection on weeds*

Data on weed flora present in the experimental field were recorded during the experimental period.

Weed Density: The weed populations were counted just at the time of first weeding, about 15 days before the expected harvest time. The population count (broadleaved, grass and sedges) were taken with the help of 0.25 m x 0.25 m quadrate thrown randomly at two places in each plot and were converted to category wise population/density per m^2.

Dry weight: While recording weed population the aboveground biomass will also be harvested from each quadrate. The harvested weeds were placed into paper bags separately and sun dried before drying in oven at a 65^{0}C temperature till constant weight subsequently the dry weight were measured.

Parameters for Weed Control

Weed Index: It will be measured from a particular treatment when compared with a weed –free treatment and will be expressed as percentage of yield potential under weed free.

$$\text{Weed Index} = \frac{x-y}{x} X\ 100$$

Where X= Yield from weed free; Y= Yield from a particular treatment

Weed Control Efficiency (WCE) - It were calculated from weed control treatments in controlling weeds.

$$\text{WCE} = \frac{(WDC-WDT)X}{WDC} 100$$

Where WDC=weed dry matter in control; WDT= weed dry matter in treatment

ii. *Data collection on crop*

Days to heading: It was recorded when the ears or panicles were fully visible on 50% of the plants from each plot by visual observation.

Plant height (cm): It was determined from measurements of 10 randomly pre-tagged mother shoots from ground level to the top of the spike excluding the awns at physiological maturity.

Number of panicles per plant: Number of panicles per plant were counted from the pre-tagged 10 plants at physiological maturity and the average were recorded as number of panicles per plant of m^{-2}.

Days to maturity: Days to maturity were measured as the number of days from emergency to the day when 85% of the plants reached physiological maturity, i.e. both panicles and plants turning yellow (senescing) based on visual observation.

Thousand grain weight: Thousand grains were counted in each plot using electronic seed counter from a bulk of threshed grain and their weight were measured using a sensitive balance at harvest and the weight were adjusted to 12% moisture content.

Total Dry Biomass (kg ha $^{-1}$*):* Total dry biomass yield including straw and panicles of plants in a net plot area were measured using spring balance after sun drying to a constant weight.

Harvesting index (%): It were calculated as the ratio of grain yield to biological yield and expressed in percentage.

$$\mathbf{HI(\%)} = \frac{\textbf{Grain Yield}}{\textbf{Biological Yield}} * \mathbf{100}$$

yield loss (YL): Percent relative yield loss were calculated as the difference of grain yield from weed free yield and weedy yield and expressed in percentage.

$$\boldsymbol{RYL} = \frac{\boldsymbol{WFY-WY}}{\boldsymbol{WFY}} * \mathbf{100}; \text{ Where,}$$

YL= Yield Loss, WFY=Weed Free Yield, WY=Weedy Yield

f) Data Analysis

Data were analyzed following a procedure appropriate to the design of the experiment [20] using appropriate statistical software. The treatment means that were significantly different at 5% levels of significance were separated using the LSD test.

III. Result and Discussion

a) Weed Parameters

i. Weed Community

The major weeds in the experimental fields were broadleaved, grassy and sedges. Fifty four weed species found infesting the experimental fields belonged to nineteen families. The major weed families competing vigorously with rice were Poaceae (12) and Asteraceae (10) and Chenopodiaceae (4). The current weed flora recorded was in accordance with the previous studies. They reported that there were as many as 350 species of more than 150 genera of 60 plant families were considered weeds of rice. Out of these, weeds of poaceae family ranked first that include more than 80 weeds [21].

Table 2: Weed community recorded in rice field at the experimental sites in 2017 cropping season

Weed species	Families	Life form
Abyssinian grass	Poaceae	Grass
Agerantum conyzoides	Asteraceae	Herb
Amaranthus graecizans L.	Amaranthaceae	A herb
Amaranthus hybridus L.	Amaranthaceae	Herb
Amharanthus spinosus L.	Amaranthaceae	Herb
Argemone mexicana L	Papaveraceae	Herb
Avena fatua L.	Poaceae	A grass
Avena vaviloviana	Poaceae	Grass
Bidens pilosa	Asteraceae	Herb
Chenopodium fasciculosum	Chenopodiaceae	Herb
Chenopodium oplifolium	Chenopodiaceae	Herb
Chenopodium opulifolium Schr.	Chenopodiaceae	A herb
Chenopodium procerum	Chenopodiaceae	Herb
Commelina benghalensis L.	Commelinaceae	Herb
Commelina latifolia A. Rich	Commelinaceae	P herb
Coreopsis borianiana	Asteraceae	Herb
Cuscuta spp	Convolvulaceae	Parasite
Cynodon dactylon (L.) Pers.	Poaceae	P grass
Cynodon nlemfuensis	Poaceae	Grass
Cynoglossum lanceolatum Forssk	Boraginaceae	Herb
Cyperus assimilis Steud	Cyperaceae	Sedge
Cyperus esculantus L.	Cyperaceae	Sedge
Cyperus rotundus L.	Cyperaceae	Sedge
Datura stramonium L.	Solanaceae	A herb
Digitaria abyssinica	Poaceae	Grass
Eleusine indica (L.) Gaertn	Poaceae	Grass

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Eragrostis cilianensis (All.) Vign. Ex Janchen	Poaceae	A grass
Galinsoga parviflora Cav	Asteraceae	Herb
Galium hamatum L.	Rubiaceae	A herb
Guzotia scabra (Vis.) Chiov.	Asteraceae	A herb
Heliotropium cinerascens Steud. ex DC.	Boraginaceae	Herb
Lantana camara L.	Verbenaceae	Shrub
Launaea cornuta	Asteraceae	Herb
Lolium temulentum L.	Poaceae	Grass
Mimosa invisa	Fabaceae	Herb
Nicandra physalodes	Solanaceae	Herb
Oldenlandia herbacea L.	Rubiaceae	Herb
Orobanche ramosa L	Orobanchaceae	Herb
Oxalis corniculata L	Oxalidaceae	Herb
Oxygonum sinuatum (Meissn.) Dammer	Polygonaceae	A herb
Parthenium hysterophorus L.	Asteraceae	A herb
Phalaris paradoxa L.	Poaceae	Grass
Polygonum nepalense Meisn	Polygonaceae	Herb
Rumex abyssinicus Jacq.	Polygonaceae	Herb
*Senna didymobotrya (*Fresen.)	Fabaceae	Herb
Setaria verticillata (L.) Beauv.	Poaceae	A grass
Snowdenia polystachya (Fresen.) Pilg.	Poaceae	A grass
Solanum nigrum L.	Solanaceae	A herb
Stellaria media L.	Caryophyllaceae	Annual
Tagetes minuta L.	Asteraceae	Herb
Tapinanthus globiferus	Loranthaceae	Annual
Tribulus terrestris L.	Zygophyllaceae	A herb
Xanthium spinosum L.	Asteraceae	A herb
Xanthium strumarium	Asteraceae	Herb

ii. *Weed density*

Effect of herbicides on weed density was clearly visible at harvest. Weed density differed significantly due to herbicidal weed management practices at harvest. Among all the treatments, the weed free treatment and weedy check plots exhibited lowest and highest weed density m^{-2} respectively at harvest. The highest number of weeds per square meter was recorded in weedy check plots followed by 2, 4-D amine salt 0.75 L ha^{-1} for broad leaves, sedges and while the lowest weed population were recorded in weed free plot followed by post - emergence application of Bispyribac-sodium 10% SC 25 g ha^{-1} and Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}. The proportion of grassy weed was higher than other weeds. Grasses persist in all of the principal crops and are a major cause for this distress. This is in accordance with the findings of [22]. The lower weed density with weed free and other herbicidal treatment might be due to inherent ability of the chemical to affect the cell division, cell growth and hampering the germination of weeds. The finding was in conformity with the finding of [23]. [24] and [25] they also reported similar results with herbicides application in rice.

iii. *Weed Dry Biomass*

The analysis of variance showed significant difference on the influence of herbicidal weed management practices on the weed dry matter at harvest. The data on dry weight of weeds at harvest was presented in Table 3. At harvest, minimum weed dry weight was registered with the application of 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE it is also stastically at par with the Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE treatment. Herbicide application resulted in significant reduction in weed dry weight over weedy check. With the increase in Bispyribac-sodium 10% SC and 2, 4-D amine salt, the weed dry weight significantly decreased, while the results were inconsistent with the application of Bispyribac-sodium 10% SC 25 g ha^{-1} and 2, 4-D amine salt 1.0 L kg ha^{-1}. The rate of 2, 4-D amine salt and Bispyribac-sodium 10% SC application may depend upon soil types, rainfall and temperature. In contrast, weedy check plots recorded highest weed dry matter (525.33gm^{-2}). [26] also reported that herbicide application decreased the dry biomass of weeds; however, this decrement depends on several factors, for example, duration of the crop, type of weed species, herbicides, fertilizer etc.

iv. *Weed control efficiency*

The highest weed control efficiency (86.7%) was recorded from 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE which was in parity with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE. The increasing rate for Bispyribac-sodium herbicide application proved more efficient than their lower rates of its application, thus; higher the weed control efficiency of a treatment, the greater was the weed control. The higher weed control efficiency could be attributed to the lower weed population and weed dry weight in these treatments. It is effective against many annual broad leaved and grassy weeds, resulting higher weed control efficiency. The results are in agreement with the findings of [27] and [9]. Among all the weed management practices, weed free plots recorded highest WCE, which might be due to decrease in weed biomass as compared to rest of the weed management practices. The highest WCE with weed free treatment also reported by [28], [29].

v. *Weed Index*

The highest weed Index (72.25%) was recorded with un weeded check, which indicated as by 72.25 per cent yield loss in un weeded check. Such yield losses due to weed competition was also reported by [30]. Among the herbicide treatments, Bispyribac-sodium 10% SC 25 g ha^{-1} (18.77%) was effective in reducing weed index followed by 2, 4-D amine salt 1.0 L kg ha^{-} (21.75 %) and Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1} (21.85 %). Better weed control efficiency and broad spectrum of control of these herbicides might have reduced weed index significantly. Similar results were reported by [31] and [30].

Table 3: Effect of weed management practices, on total weed density (m^{-2}) and dry biomass (gm^{-2}), weed control efficiency and Weed index at harvest of rice in 2017 cropping season

	Weed density	Weed dry biomass	WCE	WI
Weed management practices				
Bispyribac-sodium 10% SC 20 g ha^{-1}	156.67^{ab}	295.63^{b}	43.73^{b}	38.322^{b}
Bispyribac-sodium 10% SC 25 g ha^{-1}	80.00^{bcd}	124.93^{c}	75.66^{a}	18.77^{c}
Bispyribac-sodium 10% SC 30 g ha^{-1}	97.33^{abc}	136.43^{c}	74.21^{a}	27.88^{bc}
2, 4-D amine salt 0.75 L ha^{-1}	168.67^{a}	398.70^{ab}	27.33^{b}	60.85^{a}
2, 4-D amine salt 1.0 L kg ha^{-1}	72.00^{bcd}	107.11^{c}	79.29^{a}	21.75^{c}
2, 4-D amine salt 1.25 L ha^{-1}	71.67^{bcd}	133.03^{c}	74.35^{a}	29.53^{bc}
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	80.00^{bcd}	123.06^{c}	76.34^{a}	21.85^{c}
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	85.33^{abcd}	140.20^{c}	73.64^{a}	22.60^{bc}
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	70.00^{bcd}	98.86^{c}	82.20^{a}	15.56^{cd}
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	62.00^{cd}	66.26^{c}	86.71^{a}	18.21^{c}
Weed free check	0.00^{d}	0.00^{c}	100.00^{a}	0.00^{d}
Weedy check	133.33^{abc}	525.33^{a}	0.00^{c}	72.25^{a}
LSD (5%)	87.36	153.84	26.92	16.36
CV (%)	57.48	50.71	24.05	33.36

CV= coefficient of variation, DAE=days after crop emergence, LSD= least significant difference, Means in the same column followed by the same letters are not significantly different at 5% level of significance

b) *Crop Parameters*

i. *Phenology and growth*

a. *Days to 85 % physiological maturity*

The physiological maturity of the rice crop was significantly affected by weed management practices. Thus, the plants in plots treated with 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE, Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE were significantly earlier in attaining 85% physiological maturity than the other treatments. The results also demonstrated that weed infestation

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throughout the growing period delayed 85% physiological maturity (Table 4). In conformity with this result, of [32] also identified that the plants in unweeded plots took the highest time to reach 90% physiological maturity. The result was in contrast to the findings of [33], who stated that treating plots with chemical and supplementing with hand weeding at intervals helped to reduce number of days to maturity in cowpea.

b. *Plant height*

Analysis of variance showed that the plant height was significantly affected due to the weed management practices. Application of herbicides alone or in combination with hand weeding resulted in significantly higher plant height than in weedy check (Table 3). The taller plant height of the treatments might be due to better nutrient utilization, accelerated cell enlargement and meristematic tissue development under least weed growth environment. This finding is in conformity with the findings of [28]; [34]. Comparable results were also reported by [35]. Similarly, in wheat plant height was remarkably increased by all weed management methods compared to weedy check [18].

Table 4: Effect of weed management practices on days to 50% flowering, days to 85% physiological maturity and plant height (cm) at harvest of rice in 2017 cropping season

	Days to 50% flowering	Days to 85 % physiological maturity	Plant height
Weed management practices			
Bispyribac-sodium 10% SC 20 g ha^{-1}	86.66^{ab}	117.66^{b}	79.80^{bcd}
Bispyribac-sodium 10% SC 25 g ha^{-1}	84.33^{ab}	115.33^{bc}	77.80^{bcd}
Bispyribac-sodium 10% SC 30 g ha^{-1}	84.33^{ab}	117.00^{bc}	87.53^{abc}
2, 4-D amine salt 0.75 L ha^{-1}	86.66^{ab}	118.33^{b}	66.73^{d}
2, 4-D amine salt 1.0 L kg ha^{-1}	85.66^{ab}	117.00^{bc}	95.53^{ab}
2, 4-D amine salt 1.25 L ha^{-1}	83.66^{b}	117.66^{b}	87.20^{abc}
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	85.33^{ab}	118.33^{b}	78.93^{bcd}
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	87.66^{ab}	117.66^{b}	74.33^{cd}
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	85.00^{ab}	115.66^{bc}	82.40^{abcd}
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	84.66^{ab}	115.33^{bc}	92.30^{abc}
Weed free check	83.66^{b}	113.66^{c}	100.33^{a}
Weedy check	88.33^{a}	122.00^{a}	43.13^{e}
LSD (5%)	4.25	3.48	18.20
CV (%)	2.93	1.75	13.35

CV= coefficient of variation, DAE=days after crop emergence, LSD= least significant difference, Means in the same column followed by the same letters are not significantly different at 5% level of significance

ii. *Yield components, yield and harvest index*

a. *Number of tiller per plant*

Number of tillers per plant recorded was significantly influenced by the weed control treatments imposed (Table 4). Weed free treatments registered highest number of tillers per plant which was significantly higher than weedy check. However, it was comparable with all other herbicides treatments, facilitating better utilization of plant nutrients by crop under reduced competition from weeds evident from better weed control efficiency and tiller production up to maximum tillering stage. The lowest number of tillers was registered with weedy check. These findings are in accordance with those of [35]. This is also in agreement with the findings of [36] and [28]. [37] observed that early post-emergence application of pyrazosulfuron-ethyl 10 to 15 g ha^{-1} significantly increased number of effective tillers per plant and grains per panicle. In contrast to this result, [38] reported that duration of weed interference did not significantly affect number of tillers per plant of irrigated common bean which could be due to more supply of water that might have increased the competitive ability of the crop.

b. *Panicle length per plant*

Analysis of variance showed that the effect of weed management practices had significant effect on panicle length (Table 4). Significantly lower number of tiller per plant, panicle length per plant and thousand seed weight (g) was recorded with weedy check. These are in conformity with the findings of [38]; [40] [41].

c. *Thousand Seed Weight*

The grains under Bispyribac-sodium 10% SC 25 g ha^{-1} plots recorded the highest weight (39.81g) which was statistically at par with 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE, Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE (Table 4). The plants raised under weed free environment utilized available resources to their maximum benefit leading to increased seed weight. Similar to the current result, [42] also reported that thousand seed weight were increased with the increasing length of weed-free conditions and decreased with the increasing length of weedy conditions.

Table 5: Effect of weed management practices on Number of tiller per plant, Panicle length per plant and thousand seed weight (g) of rice in 2017 cropping season

	Number of tiller per plant	Panicle length per plant	Thousand seed weight (g)
Weed management practices			
Bispyribac-sodium 10% SC 20 g ha^{-1}	14.00^{abc}	10.40^{bc}	35.37^{bcd}
Bispyribac-sodium 10% SC 25 g ha^{-1}	17.06^{a}	12.60^{ab}	39.81^{a}
Bispyribac-sodium 10% SC 30 g ha^{-1}	13.40^{abc}	10.66^{bc}	37.27^{abcd}
2, 4-D amine salt 0.75 L ha^{-1}	11.13^{bc}	11.20^{bc}	33.22^{d}
2, 4-D amine salt 1.0 L kg ha^{-1}	15.26^{ab}	12.00^{abc}	37.06^{abcd}
2, 4-D amine salt 1.25 L ha^{-1}	13.13^{abc}	12.00^{abc}	36.42^{abcd}
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	12.93^{abc}	10.06^{bc}	37.40^{abc}
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	14.66^{ab}	12.53^{abc}	36.02^{abcd}
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	15.33^{ab}	12.86^{ab}	37.98^{ab}
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	14.93^{ab}	11.98^{abc}	39.63^{a}
Weed free check	18.13^{a}	14.20^{a}	39.14^{ab}
Weedy check	8.86^{c}	9.73^{c}	33.48^{cd}
LSD (5%)	5.30	2.84	4.07
CV (%)	22.27	14.39	6.52

d. *Grain Yield*

Grain yield of rice influenced significantly by various weed control treatments. The weed free treatment recorded significantly higher grain yield of 5701.9 kg ha^{-1}, among all the treatments. The weedy check treatment produced significantly lowest grain yield ha^{-1} among all the treatments. The weed free check treatment recorded 43.76% higher yield over weedy check. Similar finding was reported by [43] and [44]. Among chemical method of weed control, significantly higher grain yield of 4776.5 kg ha^{-1} was produced with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE which was at par with 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE (4618.0) and Bispyribac-sodium 10% SC 25 g ha^{-1}(4612.5); those treatments recorded with 41.06 %; 40.41 % and 40.27 higher yield over weed check respectively (Table 5). The increased grain yield with these treatments is due to reduced weed density, weed biomass and better weed control efficiency along with improvement in yield attributes like number of effective tillers per plant, panicles length, and 1000 grain weight. This corroborates with the findings of [45]. On the other hand, significantly lower yield was obtained in weedy check than the other treatments. The minimum yield in unweeded check is the result of severe weed competition by uncontrolled weed growth. Similar findings were also reported by [22].

e. *Aboveground Dry Biomass Yield*

Like grain yield, the aboveground dry biomass yield was also highly affected by weed management practices. The highest aboveground dry biomass yield (10797 kg ha^{-1}) was obtained in 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE treated plots which was statistically at par with 2, 4-D amine salt 1.0 L kg ha^{-1}, Bispyribac-sodium 10% SC 25 g ha^{-1} at all the application rates, and all the herbicide mixtures. Weedy check plots had the lowest aboveground dry biomass yield among the treatments (Table 5). Prolonged weed competition resulted in reduced biomass accumulation and lesser panicle length per plant and thousand seed weight which ultimately translated into lower grain yield. Increased biomass accumulation by weeds with the increasing span of weed interference period might also be a plausible cause of yield reduction in rice. As [46] stated, weed dry matter has been found to be highly correlated with crop yield loss.

f. *Harvest Index*

The result indicated that there was significant variation on harvest index among the weed management treatments evaluated. Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE gave the highest harvest index (45.13%) while the lowest harvest index (26.85%) was recorded for weedy check (Table 3). The findings of present study are in conformity with the results obtained by [47]; [48] and [49].

g. *Yield Loss*

The weeds under different weed management treatments caused variability in the amount of grain yield loss in rice. The highest yield loss (62.44%) was recorded in weedy check. This was statistically in parity with the loss registered with the application of 2, 4-D amine salt 0.75 L ha^{-1}. All these weed management practices recorded a significant yield loss compared to other treatments. Weeds are the principal limiting biological factor in global rice production, with losses that vary from country to country, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers [50]. Worldwide, it is estimated that weeds cause 9% of rice crop losses [51], with reductions in rice paddies of 94% to 96% in the Philippines [10]; in Colombia, losses of 30% to 73% have been reported [52]. Appropriate control methods in rice crops are essential to minimize the negative effect of weeds [53]. This difference in decrease in rice yield reported by various researchers might be due to the differences in weed flora, crop varieties and environmental conditions prevailing in the study area. Therefore, the difference in time of weed removal might have contributed to this variation in yield. The herbicides might have dissipated soon from the soil under the influence of environmental conditions prevailing during the crop season.

Table 6: Effect of weed management practices on grain yield, aboveground dry biomass, harvest index and yield loss of rice in 2017 cropping season

	Grain Yield	Aboveground Dry Biomass Yield	Harvest Index	Yield Loss
Weed management practices				
Bispyribac-sodium 10% SC 20 g ha^{-1}	3554.3^{c}	10490.8^{a}	35.72^{abc}	40.71^{ba}
Bispyribac-sodium 10% SC 25 g ha^{-1}	4612.5^{b}	11043.6^{a}	41.90^{a}	22.17^{b}
Bispyribac-sodium 10% SC 30 g ha^{-1}	4085.2^{bc}	11141.4^{a}	38.15^{ab}	32.96^{b}
2, 4-D amine salt 0.75 L ha^{-1}	2223.6^{d}	8820.9^{bc}	29.87^{bc}	56.01^{a}
2, 4-D amine salt 1.0 L kg ha^{-1}	4468.2^{bc}	10791.2^{a}	41.34^{a}	24.78^{b}
2, 4-D amine salt 1.25 L ha^{-1}	4038.5^{bc}	10314.5^{ab}	38.98^{ab}	32.28^{b}
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	4440.8^{bc}	11029.6^{a}	40.20^{ab}	27.25^{b}
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	4385.9^{bc}	10585.5^{a}	41.40^{a}	26.91^{b}
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	4776.5^{b}	10558.4^{a}	45.13^{a}	21.38^{b}
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	4618.0^{b}	11665.8^{a}	41.72^{a}	22.03^{b}
Weed free check	5701.9^{a}	10705.2^{a}	45.63^{a}	18.68^{b}
Weedy check	1580.4^{d}	8439.1^{c}	26.85^{c}	62.44^{a}
LSD (5%)	919.32	1568.9	11.15	22.26
CV (%)	13.43	8.85	16.92	

CV= coefficient of variation, DAE=days after crop emergence, LSD= least significant difference, Means in the same column followed by the same letters are not significantly different at 5% level of significance

c) *Partial Budget Analysis*

The result of the partial budget analyses showed that Weed free check accrued 25.5 and 26.6% higher total variable cost than Bispyribac-sodium 20 g ha^{-1} and 2, 4-D amine salt 0.75 L ha^{-1} both superimposed with hand weeding, respectively (Table 6). On the other hand the highest net benefits were obtained with the application of Bispyribac-sodium 10% SC 25 g ha^{-1}, followed by 2, 4-D amine salt 1.0 L kg ha^{-1}.

In agreement with the result, most studies showed that, applying herbicide or herbicide plus manual weeding was more economical than manual or hand weeding alone [54].

Table 7: Results of partial budget analysis of weed management practices in rice in 2017 cropping season

	Average yield (kg ha^{-1})	Adjusted yield (kg ha^{-1}) 10% down	Total variable cost (ETB ha^{-1})	Gross return (ETB ha^{-1})	Net return (ETB ha^{-1})
Weed management practices					
Bispyribac-sodium 10% SC 20 g ha^{-1}	3554.3	3199	8708	47983	39275
Bispyribac-sodium 10% SC 25 g ha^{-1}	4612.5	4151	10217	62269	52052
Bispyribac-sodium 10% SC 30 g ha^{-1}	4085.2	3677	9565	55150	45585
2, 4-D amine salt 0.75 L ha^{-1}	2223.6	2001	6912	30019	23107
2, 4-D amine salt 1.0 L kg ha^{-1}	4468.2	4021	10022	60321	50299
2, 4-D amine salt 1.25 L ha^{-1}	4038.5	3635	9502	54520	45018
Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}	4440.8	3997	10025	59951	49926
Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}	4385.9	3947	9951	59210	49259
Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE	4776.5	4299	14108	64483	50374
2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE	4618	4156	13894	62343	48449
Weed free check	5701.9	5132	18948	76976	58028
Weedy check	1580.4	1422	2134	21335	19202

The hand wedding is laborious and generally more expensive. From the computation of weed control cost it was observed that the maximum cost of weed control (11250 ETB ha^{-1}) was required for the treatment weed free check which was due to maximum labour requirement followed by Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE, 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE which may be due to high volume of herbicide and labour cost. Similar results on the weed control costs were as also observed by [25].

In weed free check, the benefit cost (3.1) was lesser even though the grain yield and gross returns were higher and was due to higher cost of cultivation as a result of high cost incurred towards labour for weeding (Table 5). Due to the severe crop weed competition throughout the crop growth period resulting in decreased growth and yield contributing parameters. Similar finding was observed by [54]. These results are also in conformity with the findings of [48] and [56].

IV. Conclusion and Recommendations

Rice is a newly introduced crop in Ethiopia. However, its importance is increasing as evidenced by the increasing in production and area covered. Due to the nature of the crop and its high productivity than other field crops, rice production in *Guraferda* district has been increasing and contributing both for income and food security of farmers. Weeds are the principal limiting biological factor in global rice production, with losses that vary from country to country, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers. Hence, the experiment was conducted in Southern Nations Nationalities Peoples Region, Ethiopia during the 2017 main cropping *'Meher'* season, in Bench Maji Zone at *Guraferda Woreda* research site. The e objectives of the study were to find out the effect of Bispyribac-sodium 10% SC, and 2, 4-D amine salt on weeds, growth, yield components and yield of rice and to investigate the possibilities of supplementing low doses of herbicides with hand weeding for effective weed control.

New Rice for Africa variety four was used for this experiment. The research was consisting of 12 treatments *Viz*: Bispyribac-sodium 10% SC (20 g ha^{-1}), Bispyribac-sodium 10% SC (25 g ha^{-1}), Bispyribac-sodium 10% SC (30 g ha^{-1}), 2, 4-D amine salt (0.75 L ha^{-1}), 2, 4-D amine salt (1.0 L kg ha^{-1}), 2, 4-D amine salt (1.25 L ha^{-1}), Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1}, Bispyribac-sodium 10% SC 10 g + 2, 4-D amine salt 1.0 L ha^{-1}, Bispyribac-sodium (20 g ha^{-1}) + hand weeding and hoeing at four-five weeks after crop emergence, 2, 4-D amine salt (0.75 L ha^{-1}) + hand weeding and hoeing at four- five weeks after crop emergence, Weed free check, Weedy check. The design of the experiment was RCBD with three replications.

The most important weeds in the experimental fields were broadleaved, grassy and sedges. The influence of herbicides on weed density was clearly visible at harvest. The lowest weed dry weight was recorded with the application of 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE it is also stastically at par with the Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE treatment. The highest weed control efficiency 86.7% was recorded from 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE which was in parity with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE. Among the herbicide treatments, Bispyribac-sodium 10% SC 25 g ha^{-1} 18.77% was effective in reducing weed index followed by 2, 4-D amine salt 1.0 L kg ha^{-} 21.75 % and Bispyribac-sodium 10% SC 20 g + 2, 4-D amine salt 0.75 L ha^{-1} 21.85 %.

The results also confirmed that weed infestation throughout the growing period delayed 85% physiological maturity. Significantly lower number of tiller per plant, panicle length per plant and thousand seed weight was recorded with weedy check. The weed free check treatment recorded 43.76% higher yield over weedy check. Among chemical method of weed control, significantly higher grain yield of 4776.5 kg ha^{-1} was produced with Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE which was at par with 2, 4-D amine salt 0.75 L ha^{-1} + hand weeding and hoeing at 35 DAE (4618.0) and Bispyribac-sodium 10% SC 25 g ha^{-1} 4612.5, those treatments recorded with 41.06 %; 40.41 % and 40.27 higher yield over weed check respectively. Bispyribac-sodium 20 g ha^{-1} + hand weeding and hoeing at 35 DAE gave the highest harvest index (45.13%) while the lowest harvest index (26.85%) was recorded for weedy check. The highest yield loss 62.44% was recorded in weedy chec. The outcome of the partial budget analyses indicated that weed free check increased 25.5 and 26.6% higher total variable cost than Bispyribac-sodium 20 g ha^{-1} and 2, 4-D amine salt 0.75 L ha^{-1} both superimposed with hand weeding, respectively. On the other hand the maximum net benefits were acquired with the application of Bispyribac-sodium 10% SC 25 g ha^{-1}, followed by 2, 4-D amine salt 1.0 L kg ha^{-1}. The hand wedding is laborious and generally more expensive. If cheaper and ample labour are available Bispyribac-sodium 10% SC 20 g ha^{-1} + hand weeding and hoeing at 35 DAE should be done. With the availability of herbicides, Bispyribac-sodium 10% SC 25 g ha^{-1} followed by 2, 4-D amine salt 1.0 L kg ha^{-1} can be used to preclude the yield loss and to obtain maximum benefits from rice.

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