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Productivity, Yield Attributes and Weed Control in Wheat (*Triticum aestivum* L.) as Influenced by Integrated Weed Management in Central High Lands of Ethiopia, East Africa

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Abstract

Wheat (*Triticum aestivum* L.) crop is often fraught with weeds in central high lands of Ethiopia which are characterized by high rainfall, low humidity and low temperatures favorable for development of diseases and insect pests resulting in dwindled productivity. Field experiment was conducted at the Research farm of Plant Science department, Ambo University, for two consecutive years (2014 and 2015) to delineate the effect of 2, 4-D alone, hand weeding alone and their integration on weed control and wheat productivity in comparison with un weeded check in a randomized complete block design with six replications. The experiment comprised four treatments (hand weeding, hand weeding + 2, 4-D @ 2.0 kgha^{-1}, 2, 4-D application @ 2.0 kg/ha and un-weeded check). The experimental site was predominantly infested with different weed species belonging to different families such as grasses, broadleaved weeds and sedges. It was found that Integrating hand weeding + 2, 4-D at 2.0 kgha^{-1} significantly reduced weed density and dry biomass of weeds in both 2014 and 2015 cropping years compared with the other weed control methods. Highest grain yield (4322, 3989 kg ha^{-1}) was recorded with hand weeding + 2, 4-D at 2.0 kgha^{-1}, followed by hand weeding (3500, 2851 kg ha^{-1}), whereas the lowest yield was recorded from un weeded check (1167, 1082 kg ha^{-1}) in 2014 and 2015 cropping seasons, respectively. Uncontrolled weed growth throughout the crop growth period caused a yield reduction of 72% in both cropping seasons. Application of Post- emergence herbicide 2, 4-D and /or hand weeding and hoeing at tiller stage could further reduce the deleterious effect of weeds on wheat crop raised in central high lands of Ethiopia.

Keywords: 2, 4-D; Hand weeding; Wheat yield; Weed density; Weed biomass; Weed control efficiency; Relative yield loss

Introduction

Wheat, since time immemorial, played a pivotal role in development of civilization and predominant in antiquity as a source of human staple food around the world. It is the cereal of the temperate regions of the world and at high altitudes in tropics and subtropics between 1600-3000 m. Wheat occupies about 17% of the world's cropped land and contributes 35% of the staple food is next only to rice, so its increased production is essential for food security [1,2]. Wheat is one of the major cereal crops grown on the Ethiopian highlands. Despite its importance in Ethiopia, the mean national yield is 1.3 tons ha^{-1} which is 24% below the mean yield of Africa and 48% below the global mean yield of wheat [2]. Yield reducing factors in wheat are soil fertility decline, weeds, disease, and insects. Weeds compete with crop plants for essential growth factors like light, moisture, nutrients and space. Weeds can also increase harvesting costs, reduce quality of product [3]. Apart from increasing the production cost, weeds also intensify the disease and insect pest problem by serving as alternative hosts, and uncontrolled weed growth throughout the crop growth caused a yield reduction of 57.6 to 73.2% [2]. Though manual and physical methods of weed control are very effective in Ethiopia, however, non availability of labor during peak period under intensive farming, high labor cost; regeneration of weeds which require frequent operation and weeds cannot effectively be managed merely due to crop mimicry [4]. Therefore, the use of chemical weed control has become necessary [5] and this has created a scope for using herbicides and they are becoming more popular in developing countries like Ethiopia. Weed management systems that depend heavily on herbicides are now accepted as unsustainable and it has also created a problem of evolution of herbicide resistant weeds [6,7]. Hence, development of more comprehensive and sustainable weed management system is warranted for economic production of wheat. Moreover, control of weeds by a single method usually does not give positive results and may also not be socio-economically acceptable. An integrated weed management involves specific control measures to be directed not only against one weed species, but also for all the species affecting a crop in a particular area [8], and crop species and cultivars that compete better is an important component of IWM [9]. Currently there is scanty information on integrated weed management approach in wheat crop in Ethiopia. Therefore, the present investigation has been made with an objective to delineate the influence of hand weeding alone, post- emergence 2, 4-D application alone and the integration of hand weeding with herbicide at low dose in comparison with un weeded check on weed control, yield and yield components of rain fed wheat raised on clay loam soils in central high lands of Ethiopia.

Materials and Methods

The present experiment was conducted for two consecutive cropping years (2014 and 2015) at Ambo University research farm. The site is located at a latitude of 9°11'0" North, 38°20'0" East and an altitude of 1980 m.a.s.l. The area received an average annual rainfall of 780 mm. The mean annual minimum and maximum temperatures are 8.25 and 23.4°C, respectively. The field experiment comprised four

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treatments: one hand weeding (25 days after sowing), 2, 4-D at 2.0 $kgha^{-1}$ (25 days after sowing), 2, 4-D at 2.0 $kgha^{-}$ (25 days after sowing)+ hand weeding (40 days after sowing) and compared with a weedy check arranged in a randomized complete block design with six replications. 2, 4-D was applied at 25 days after sowing as post-emergence with the help of Knapsack/Backpack sprayer. The spray volume was 600 L of water per ha. The size of each plot was 1.0 m × 2.0 m. The distance between adjacent replications and plots was 1 m and 0.5 m, respectively.

Wheat variety HAR 604 was planted at recommended seed rate of 150 kg ha^{-1} in plots. Fertilizer was used at the rate of 64 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} through di-ammonium phosphate (DAP) and urea. Half of nitrogen and full dose of phosphorus was drilled in rows at the time of sowing and the remaining N through urea was applied at shoot elongation stage of crop. The weed population count was taken with the help of 0.25 m × 0.25 m quadrant thrown randomly at three places in each plot and was identified and converted to population density per m^2 at 60 days after sowing. After recording weed population the biomass was harvested from each quadrant. The harvested weeds were placed into paper bags separately and then dried in oven at a 65°C temperature for 24 h. till constant weight and subsequently the dry weight was measured and converted into gm^{-2}. Weed Control Efficiency (WCE) was calculated from weed control treatments in controlling weeds:

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

Where WDC: Weed Dry Matter in Weedy Check; WDT: Weed Dry Matter in a Treatment. Tillers per meter row length, plant height, grains per spike, thousand kernel weight, grain yield and relative yield loss were recorded. The final produce was measured and adjusted to 12.5% moisture content with the help of the following formula:

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

Where, M is the measured moisture content in grain and D is the designated moisture content.

Relative yield loss due to weeds was calculated based on the maximum yield obtained from a treatment /treatment combination.

$$\text{Relative yield loss}=\frac{MY-YT}{MY}\times 100,$$

Where, MY= maximum yield from a treatment, YT = yield from a particular treatment.

Harvest index (%): It was calculated by

$$HI=\frac{\text{Grain yield}}{\text{Total aboveground dry biomass yield}}\times 100$$

Population density of weeds was subjected to square root transformation $\left(\sqrt{(X+0.5)}\right)$ to have data normal distribution. Data were subjected to analysis of variance and mean separation was conducted for significant treatment means using Least Significance Differences (LSD) at 5% probability level.

Results and Discussion

Weed floral composition of the experimental site

The experimental site was infested with different weed species belonging to different families. The predominant wed flora comprised *Avena fatua* L., *Cynodon dactylon* L., *Phalaris minor* L., *Poa annua* and S*nowdenia polystachia* L were among the grass weeds, and *Amaranthus hybridus* L., *Biden pilosa* L. *Chenopodium album* L., *Commelina benghalensis* L, *Commelina arvensis* L, *Datura stramonium* L., *Galinsoga palviflora, Nicandra physelodes Oxalis latifolia* HBK, Polygonum *nepalense* L., and *Raphanus raphanistrum* L., were among broadleaved weeds and *Cyperus esculentus* L. was the only sedge weed. This indicated that a species-rich weed community existed in the experimental field.

Weed density

Effects of different weed control methods on weed density were significant. The results showed (Table 1) that the lowest weed density (10.45, 7.49 m^{-2}) was recorded in plot treated with 2,4-D at 2.0 $kgha^{-1}$+ hand weeding followed by hand weeding (11.89, 14.77 m^{-2}) whereas the maximum was recorded in weedy check (14.16, 27.4 m^{-2}), respectively during 2014 and 2015. However, no significant difference was observed between hand weeding and 2,4-D at 2.0 $kgha^{-1}$+ hand weeding .These results are in agreement with Raize et al. [6] and Bibi et al. [3] who reported herbicides supplemented with cultural practices (hand weeding) improved weed controlling ability. When there is sufficient moisture up to grain filling, 2,4-D was found most economical under high broad leaf infestation in barley [10].

Weed biomass

The different weed control methods exhibited significant influence on the dry weight of weeds at both growing periods. The lowest dry weight of weeds (5.1, 6.93 gm^{-2}) was recorded in plot treated with 2,4-D at 2.0 $kgha^{-1}$+ hand weeding, followed by hand weeding (16.0 gm^{-2}, 26.7 gm^{-2}). Whereas the highest biomass was observed in weedy check (50. gm^{-2}, 207.47a gm^{-2}) during 2014 and 2015, respectively (Table 1). These results are in tandem with those reported by Raize et al. [6] and Tesfay [2] who reported post- emergence herbicides and /or hand weeding and hoeing at tillering stage reduced the dry weight of weeds as compared to herbicides alone or weedy check.

Weed control efficiency

The data presented in Table 1 revealed that during 2014, the minimum weed control efficiency was observed in weedy check

Treatments	Weed density (m^{-2})		Weed dry biomass (gm^{-2})		WCE (%)	
	2014	2015	2014	2015	2014	2015
Hand weeding	11.89(141.3)bc	14.77(218.67)c	16.0c	26.67bc	68.2c	87.1b
2,4-D at 2.0 $kgha^{-1}$ + Hand weeding	10.45(108.8)c	7.49(58.67)b	5.1d	6.93c	89.9d	96.7a
2,4-D at 2.0 $kgha^{-1}$	12.57(158.7)ab	18.31(336.00)b	32.8b	44.8b	34.8b	78.4c
Weedy check	14.16(200.3)a	27.4(752.0)a	50.3a	207.47a	0.0a	0.0a
LSD(0.05)	1.73	3.87	7.44	25.86	11.66	2.86
CV (%)	7.04	10.86	14.31	17.24	11.48	12.09

Figures or numbers in the parenthesis are original values,

LSD: Least Significant Difference; CV: Coefficient Of Variation; WCE: Weed Control Efficiency.

Table 1: Effect of weed control methods on weed density (m^{-2}), weed dry biomass ($gm^{-2)}$ and weed control efficiency (%) during 2014 and 2015 cropping seasons.

(0.00%) whereas the highest (100.0%) was recorded in a plot treated with hand weeding +2, 4-D at 2.0 kgha^{-1}. Similarly during 2015, the maximum weed control efficiency (96.7%) was recorded in 2,4-D at 2.0 kgha^{-1}+ hand weeding, followed by hand Weeding (52.5.) ,whereas the minimum efficiency was observed in weedy check (0.0%). This result further elucidates that herbicide application supplemented by hand weeding is more effective in reducing weed density and dry biomass weights of weeds next to hand weeding as compared to weedy check. This result was in accordance with Raize et al. [6] who reported that herbicides supplemented by hand weeding gave higher weed control efficiency which could be due to the complementary effect of hand weeding and/herbicides.

Wheat yield and yield attributes

Plant height (cm): The effect of weed management practices on plant height was not discernible (Table 2). This could be due to availability of abundant of growth promoting factors in weed free plot that allowed the plants to attain their maximum height, the competition between weeds and crop for sun light and space in unweeded plots resulted in tall stature of plants. Thus, there was no distinct variation in plant height with different treatments.

Tiller number (m^1): Effect of weed management practices on number of tillers per plant was significant. It was found that the highest number of tillers per meter row length (169.9,174.6) was observed with 2,4-D at 2.0 kgha^{-1}+ hand weeding, followed by hand weeding (146.6, 155.3), whereas it was the lowest in weedy check (82.7, 121). This was due to more effectiveness of these treatments on weed control that resulted in lower weed density and dry weight thus reduced crop-weed competition that contributed to more number of tillers per plant in comparison with un weeded check .Reduction in number of tillers, and productive tillers in barley with increased weed density was also reported earlier by Takele which supports the current findings [11].

Grains per spike: Different weed control methods influenced the grains per spike significantly where in the highest number of grains per spike was recorded with 2,4-D at 2.0 kgha^{-1}+ hand weeding, closely followed by hand weeding. The lowest grains per spike was recorded in weedy check during both the years of experimentation. The grains per spike in 2015 were low compared with 2014 which can be attributed to greater weed density and weed biomass exerting greater competitive stress on wheat. Considerable enhancement in grains per spike due to integrated treatment was probably due to reduced weed competition and availability of adequate quantities of plant nutrients and moisture to crop plants. Similar result was also reported earlier by Raize et al. [6].

Thousand kernel weight: The data presented in Table 2 showed that thousand kernel weight was significantly affected by weed control methods during 2014 and 2015 cropping seasons. The highest (69.6, 76.7 g) thousand grain weight was recorded from plot treated with 2,4-D at 2.0 kgha^{-1}+ hand weeding, followed by hand weeding (54.2, 69.1 g). The minimum was recorded from weedy check (32, 51.5 g) during 2014 and 2015, respectively. The weeding at proper time employing herbicide and supplementing with hand weeding could provide favorable environment for the crop which ultimately lead to better grain filling. This is quite possible that weed free crop stand produced robust grains and ultimately resulted in more 1000-grain weight. Takele also reported a decline in test seed weight with increasing weed density in central high lands of Ethiopia [11]. Similar results have also been reported earlier by Narkhede et al. [12], Tomar et al. [13].

Grain yield (kg/ha): Grain yield was significantly influenced by different weed management practices during 2014 and 2015 cropping season (Table 3). Among weed management practices, the highest grain yield (4322, 3989 kg ha^{-1}) was recorded with 2,4-D at 2.0 kgha^{-1}+ hand weeding, followed closely by hand weeding (3500, 2851 kg ha^{-1}), while the lowest yield was recorded in weedy check (1167, 1028 kg ha^{-1}). The enhancement in wheat grain productivity with integrated approach could be attributed to suppression of weed density, weed growth and biomass that favored increase in yield attributes such as number of tillers per meter row length, grains per spike and test seed weight. Reduction in grain yield with increased weed density was also reported earlier by Takele which corroborates the present findings [11]. Application of 2, 4-D alone could only control broad leave weeds, leaving grassy weeds which competed with the crop at later stages resulting in considerable yield reduction. Significantly higher yield in weed control treatments compared to weedy check has also been reported by Pandey and Mishra [14] and Roslon and Fozelfors [15].

Treatments	Plant height (cm)		Tiller No(m^{-1})		Grains per spike (no)		TKW(g)	
	2014	2015	2014	2015	2014	2015	2014	2015
Hand weeding	96.3	74.67	146.6c	155.3b	23.1b	8.3ab	54.2b	69.1ab
2,4-D at 2.0 kgha^{-1} + Hand weeding	82.4	77.53	169.9a	174.6a	29.0a	10.8a	69.6a	76.7a
2,4-D at 2.0 kgha^{-1}	76.0	70.96	153.3b	149.67c	18.8c	7.4b	56c	65.5b
Weedy check	79.2	69.83	82.7d	121d	15.0d	5.8b	32d	51.5b
LSD(0.05)	NS	NS	2.2	4.11	2.0	3.03	5.9	8.41
CV (%)	11	7.66	20.7	20.42	13.8	17.89	12.3	6.10

LSD: Least Significant Difference; CV: Coefficient of Variation; TKW: Thousand Kernel Weight.

Table 2: Effect of weed control methods on plant height, tiller number, grains/spike and thousand kernel weight in wheat during 2014 and 2015 cropping seasons.

Treatments	Grain yield(kgha^{-1})		HI (%)		RYL (%)	
	2014	2015	2014	2015	2014	2015
Hand weeding	3500.0b	2851.1a	25.12b	26.3b	16.4c	28.2b
2,4-D at 2.0 kgha^{-1} + Hand weeding	4322.2a	3988.9a	31.56ab	29.7a	0.0d	0.00c
2,4-D at 2.0 kgha^{-1}	2444.4c	2526.7b	22.21b	20.6c	41.5b	36.3b
Weedy check	1166.7d	1082.2c	11.4c	9.8d	72.0a	72.7a
LSD(0.05)	802.31	746.3	5.41	1.9	14.89	16.44
CV (%)	14.17	13.61	11.39	9.7	22.93	22.84

HI: Harvest Index; RYL: Relative Yield Loss

Table 3: Effect of weed control methods on grain yield, harvest index and relative yield loss during 2014 and 2015 cropping season.

Wogayehu Worku et al. [16] reported no significant difference between herbicides Tomahawk, Herb knock, Draget –SD, U-46, and wheat yield advantage of 37, 36, 32 and 32%, respectively was observed over weedy check in West Shoa zone of Ethiopia. Experiments conducted at Sinana with eleven herbicides compared with hand weeding showed that one hand weeding was economical, and in Bale 3 herbicides gave 33%yield advantage over weedy check as reported by SARC [17].

Harvest index: The effect of different weed control methods on the harvest index of wheat, an indicator of assimilate partitioning efficiency, was statistically significant during both years of study. The data presented in Table 3 showed that the highest harvest index (31.56, 29.7%) was recorded with 2, 4-D at 2.0 kgha^{-1} supplemented by hand weeding, whereas the lowest harvest index was from weedy check (11.4, 9.8%). The significant increase in harvest index with integrated weed management may be attributed to suppression of weed growth resulting in more availability of plant nutrients, soil moisture and space to wheat crop, which favored utilization of photo synthates for better grain yield formation.

Relative yield loss: While comparing the loss in wheat yield due to the weed management practices, it was observed that the lowest yield loss (0.0, 0.0%) was recorded with 2,4-D at 2.0 kgha^{-1}+ hand weeding as compared to the rest of the treatments. This was followed by hand weeding (16.4, 28.2) and 2, 4-D at 2.0 kgha^{-1} (41.5, 36.3%), Whereas the loss was highest (72.0, 72.7) in weedy check (Table 3) during 2014 and 2015, respectively. The higher yield loss in 2, 4-D at 2.0 kgha^{-1} may be due to greater density of grassy weeds in the current field experiment. By and large, herbicides minimize crop yield loss when supplemented with had weeding or other cultural practices. These results are in corroboration with Tesfay who reported that uncontrolled weed growth throughout the crop growth caused a yield reduction to the tune of 57.6 to 73.2%in Ethiopia [18-22].

Conclusion

From the results of the two year field experiment it could be inferred that, among the weed management practices, post emergence application of 2, 4-D at 2.0 kgha^{-1} at 25 days after sowing, supplemented with hand weeding at 40days after sowing reduced weed density and dry biomass of weeds significantly, closely followed by hand weeding. These treatments also enhanced yield and yield components significantly and reduced relative yield loss of wheat. Application of 2,4-D alone could not prove effective in controlling weeds, thereby resulting in more yield loss in comparison with hand weeding and integrated approach. Uncontrolled weed growth throughout the crop growth period caused a yield reduction of 72% and 72.7% in wheat during 2014 and 2015 cropping seasons, respectively.

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