

**EFFECTS OF SEED RATES AND HERBICIDES APPLICATION ON
WEED MANAGEMENT AND PRODUCTIVITY OF WHEAT (*Triticum
aestivum* L.) AT HOLETA ETHIOPIA**

MSc. THESIS

BY

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**Effects of Seed Rates and Herbicides Application on Weed Management
and Productivity of Wheat (*Triticum aestivum* L.) at Holeta Ethiopia**

By

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DEDICATION

I would like to dedicate this thesis manuscript to my parents in general, my beloved brother Desalegn Ayana, my sisters Bontu Ayana, Mulunesh Ayana and very especially to my beloved mother Askale Tirfe for their continuous encouragement but also for their patience and understanding throughout the course of my studies.

STATEMENTS OF AUTHOR

I am here by declaring that this MSc. Thesis is my own original work and it has not been presented and will not be presented to any other University for a similar or any other degree award. Brief quotations from this thesis are allowable without special permission provided that accurate citation of source is made.

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The author, Bogale Ayana was born on 12th November, 1988 G.C in Oromia region, South West Shewa Zone, Weliso woreda. He started primary school in Maru Korme and Dilela primary Schools from 1998 to 2005 G.C and also went to Dejazmach Geresu Duki Comprehensive Secondary High school and Preparatory school at Weliso town from 2006–2009 G.C. He also attended higher education from 2010-2012 G.C at Ambo university and graduated with Bachelor of Science Degree in Plant Science from faculty of Agriculture in 2012G.C.He has been employed at Ethiopian Institute of Agricultural Research at Holeta Agricultural Research Center and served at various capacity from May, 2014 G.C to September, 2018 G.C as junior and assistance researcher for three years and five months. He got the chance learning to pursue MSc. Degree in plant protection at Jimma University, College of Agriculture and Veterinary Medicine in October 2018 G.C.

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LISTS OF ABBREVIATIONS AND ACRONYMS

CIMMYT	International Maize and Wheat Improvement Center
DAP	Days After Planting
HI	Harvest Index
OD	Oil Dispersible
SC	Soluble Concentrate
WG	Wettable Granule
YL	Yield Loss

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Effects of Seed Rates and Herbicides Application on Weed Management and Productivity of Wheat (*Triticum aestivum* L.) at Holeta Ethiopia

ABSTRACT

Wheat is one of the most important food security crops which is cultivated from small to large scale farms in Ethiopia. However, its productivity has been limited due to various abiotic and biotic factors including weeds. The aim of the study was to investigate the effects of seed rates and post emergence herbicides application on weed management and productivity of wheat. Factorial combinations of three levels of seed rates (100,150 and 200 kg ha⁻¹) and four types of herbicides (Agro 2,4-D 720 g/L 1lt ha⁻¹, Pallas 45 OD 0.5lt ha⁻¹, Derby 175 SC 100ml ha⁻¹ and Lancolet 450 WG 33 gm ha⁻¹) along with control (a weedy check) were laid out in RCBD with three replications. A total of identified 12 weed species were recorded (86 % broad and 14 % grass weeds). Results also revealed that significant effects of seed rate by herbicide interaction for all the traits studied. The minimum weed densities (4.52m⁻² and 2.7m⁻²) at 25 and 45 days after planting (DAP), dry biomass of grass weeds (33.33 kg ha⁻¹) and the highest weed control efficiency (81.22%) were recorded from the interaction effects of 150 seed rate with pallas 45 OD while the minimum dry biomass of broad leaf weeds (53.33 kg ha⁻¹) was recorded at 200 kg ha⁻¹ seed rate with lancolet 450 Wettable Granule (WG). The highest number of productive tillers (133.33m⁻²), seeds per spike (76.48), thousand grain weight (44.36g), grain yield (4516.42kg ha⁻¹) and biological yield (13100kg ha⁻¹) were recorded from the combination of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the lowest values were observed from the weedy check. Grain yield had strong positive correlations with each of the yield components, however it was negatively correlated with dry weed biomass. Based on partial budget analysis, the maximum net benefit was obtained from the interaction of 150 kg ha⁻¹ seed rate with pallas 45 OD but higher number of marginal rate of return was calculated from 150 kg ha⁻¹ seed rate with 2,4-D. It was also observed that, the combined use of seed rate 150 kg ha⁻¹ with Pallas 45 OD effectively managed weeds, economical and gave maximum yields, which could be recommended for the test environment. Since the experiment was conducted in one location and for a single season, it should be repeated over seasons or multi locations for best recommendation.

Key words: combination, effect, interaction, maximum, Pallas 45 OD

1. INTRODUCTION

Wheat belongs to the family Poaceae and the genus *Triticum* which was cultivated under small to large scale farms in Ethiopia. The global annual wheat production is 731.6 million tons from an area of 215.87 million hectares giving an average yield of 3.39 tons ha⁻¹ (USDA, 2019). In Ethiopia, it is one of the major staple and strategic food security crops with an average annual production and productivity of 4.64 million metric tons and 2.73 tons ha⁻¹ respectively (CSA, 2018). Bread wheat is known to be a major source of energy and protein. Traditionally the crop is used for making Bread, Porridge and other types of foods. The straw is good source for animal feed and also used for thatching roofs (Mathewos *et al.*, 2012).

Although wheat has a great nutritional and economic importance, its productivity has been constrained due to various biotic and abiotic factors. Yield reducing factors in wheat are soil fertility decline, weeds, disease, and insect pests (Bekele *et al.*, 2018). Among the biotic factors weeds are one of the major constraints in wheat production as they reduce productivity due to competition, allelopathy and by providing habitats for pathogens as well as serving as alternate host for various insects, fungi and increase harvest cost (Haile and Girma,2010). The yield loss assessment conducted in Ethiopia suggested that there is an average yield reduction up to 36% due to weed competition (Rezene 1986; Hailu *et al.*, 1991). Tanner and Giref (1991) also found that weeds are a significant threat to wheat production in Ethiopia, causing yield loss of up to 70% in some growing seasons.

In Ethiopia, where wheat is cultivated, poor weed management, indefinite and below optimum plant population used by the farmers appear to be the major limiting factors resulting in low productivity of wheat (Zegeye *et al.*, 2001). In most cases, wheat is grown in the country without appropriate seed rate, sometimes farmers use below optimum seed rate that resulted in poor stand establishment encouraging growth of weeds (Abdulkerim *et al.*, 2015). On the other hand, use of higher seeding rate may exacerbate problems like lodging, insect and disease infestation and damage that harm crop yield (Merga and Ahmed, 2019).

Seeding rate, percent viability and germination of seeds usually determine crop density. Normally, higher the density of a crop, lower is weed competition and vice-verse (Babu *et al.*, 2017). The crop density however, cannot be increased arbitrarily and indefinitely since every crop has an optimum population beyond which intraspecific competition among crop plants

may occur. Moreover, economic benefit of using higher seeding rate should also be taken into account. It is also quite important to address plant density with respect to soil fertility, wheat variety, and agro-ecology (Babu *et al.*, 2017).

The weed controlling methods utilized so far are laborious, tiresome and expensive due to increasing cost of labor, draft animals and farm implements at small scale farms in Ethiopia. To date, the use chemical weed control has becoming popular worldwide and in Ethiopia in particular mainly due to scarcity or expensive labor during peak of growing season and relatively the higher weeding cost (Haile and Girma, 2010). However, the choice of most appropriate herbicide, proper time of application and proper dose is an important consideration for lucrative returns (Tigabu and Asfaw, 2016). In addition, continuous use of a single herbicide or herbicides of the same family or mechanism of action eventually resulted in weed resistance, herbicide persistence as well as the buildup of toxic residues in food chain, toxic effects to humans and animals (Birhanu, 1985; Rezene, 1985).

Previous studies showed that the application of broad spectrum herbicides decreased dry weight of weeds significantly compared to dry weight in non-treated plots and increased yield components and grain yield of wheat (Akhtar *et al.*, 1991; Ahmed *et al.*, 1993). Several researches have been done for the control of broadleaf weeds by application of hand weeding 2, 4-D, Pallas 45 OD, Derby 175 SC and other post emergence herbicides for broad leaf weed management of wheat in Ethiopia (Megersa *et al.*,2017; Zahara and Shigute,2017;Bekele *et al.*,2018). Frehiwot *et al.* (2012) reported that the application of Pallas 45 OD 20 g ha⁻¹ reduced the dry weight of serious grassy weeds on bread wheat. However, limited applicable technology has been adopted to control grass weed species in wheat. Hand weeding failed to control most grasses especially wild oat which resembles the crop at early stage of growth and caused the greatest yield loss as they compete with the wheat crop throughout the growing season which was difficult to apply for large scale farms. Hence, the introduction of any weed management technology which is economically and agronomical feasible should be investigated for the management of weeds wheat. Further, the yield loss estimation and economic advantages of using appropriate seed rate for better weed management and gaining higher yield not well practiced by most of small scale farms in Ethiopia. However, studies on seed rates in relation with broad spectrum herbicides on various broad leaf and grass weed

species management to increase the productivity of wheat remains limited in Ethiopia. Therefore, this study was initiated with the following objectives:

- To evaluate the effects of different levels of seed rates and herbicide types on weed management and productivity of wheat (*var. Dendea*) at Holeta Ethiopia
- To determine the economically optimum level of seed rate and effective herbicide type.

2. LITRATURE REVIEW

2.1 Wheat production and ecology

In Ethiopia, wheat was planted to 13.38% (1,696,907.05 hectares) of the grain crop area in 2018/19 cropping season (CSA,2018).The production obtained from wheat was 15.17% (46,429,657.12 quintals) of the grain production and yield of 2.73 t ha⁻¹ (CSA, 2018).Some of the common bread wheat varieties under production in Ethiopia includes: *Dendea, Digelu, Kekeba, Galema, Alidoro, Hidassie, Kubsa, Batu, Mitike, Wabe, Simba, Hawi, Warera, Dure, Dodota, Meraro, Abolla, Pavon, Dashen, Kenya -1, Densa, Simbo, Megal, Enkoy and Laketch* (HAR,2019).

Table 1.Wheat production regions of Ethiopia under private peasant holdings for 2018/19 Meher Season (CSA,2018).

Regions	No of holders	Area of production (ha)	Production ton/ha	Yield ton/ha
Tigray	312708	107929.86	214003.14	1.98
Afar	-	-	-	-
Amhara	1645432	554661.74	1404707.481	2.53
Oromia	1713504	898682.57	2669917.77	2.97
Somali	-	-	-	-
BenishangulGumuz	8455	2455.71	5908.35	2.41
SNNP	525386	127246.59	34919.60	2.67
Gambella	-	-	-	-
Harari	3405	-	-	-

Wheat can be cultivated in a wide range of agricultural environments (Farooq *et al.*, 2009). It can grow over a wide range of elevations, climatic conditions, and soil fertility conditions. The crop is grown at an altitude ranging from 1500 to 3000 meters above sea level (m.a.s.l.) between 6-16°N latitude and 35- 42°E longitude in Ethiopia. The most suitable agro-ecological zones, however, fall between 1900 and 2700 m.a.s.l. (Bekele *et al.*, 2000). Even though the optimal growing temperature is 25°C, it can be grown in temperatures ranging from 3 to 32°C. The ideal daily temperature for different stages of wheat development varies from 20-25°C for germination, 16-20°C for good tillering and 20-26°C for proper plant development. The optimal rainfall for wheat is between 900-1100 mm throughout the growing season, but wheat can be grown in xerophytic to littoral moisture regimes with average annual

rainfall between 250 to 1750 mm. Wheat can be grown under different soil types but well-drained fertile loamy to sandy loam soil with a P^H of 6 to 7.5 is suitable for its growth (Tana *et al.*, 2018).

2.2 Weed species composition and competition in wheat

2.2.1 Common weed species associated with wheat

Wheat field infested by variety of weed species belonging to different families. The weed flora composition assessment in wheat fields in Ethiopia showed that *Avena abyssinica* L., *Avena fatua* L., *Bromus pectinatus* L., *Lolium temulentum*, *Phalaris paradoxa* L., *Setaria pumila* L., and *Snowdenia polystachya* L. are the major problematic weed species in wheat growing regions (Birhanu, 1985; Rezene, 1985; Tanner and Grief, 1991).

The most widely spread and distributed broadleaved weeds and most problematic weeds in wheat crop weeds include: *Amaranthus hybridus* L., *Argemone mexicana* L., *Bidens pilosa* L., *Commelina africana* L., and *Chenopodium album* L. *Convolvulus arvensis* L., *Datura stramonium* L., *Galinsoga parviflora* Cav., *Guizotia scabra* (Vis) Chiov, *Medicago polymorpha* L., *Polygonum nepalense* L., *Plantago lanceolata* L. and *Scorpiurus muricatus* L. (Rezene, 1985; Tanner and Giref, 1991).

2.2.2 Weed-crop competitions for growth resources

The word competition comes from the Latin word compete, which means to ask or sue for the same thing another does. Competition in biology, ecology and sociology is a contest between organisms, animals, individuals, groups, etc., for territory, a niche or a location of resources, for resources, mates, for prestige, recognition, awards or group or social status for leadership. According to Thompson, and Grime (1979) competition is established when neighboring plants use the same resources and success in competition is strongly determined by the plant capacity to capture these resources. Thus, a good competitor has a high relative growth rate and can use the available resources quickly. However, Tilman (1980) claims that competitive success is the ability to extract scarce resources and to tolerate this lack of resources – essentially to be more efficient in extracting and using a given resource. Competition between

plants is different from the competition between animals. Due to the lack of mobility, the Competition among plants apparently is passive, not being visible at the beginning of the development (Munch *et al.*, 2008). It is known, however, that crops in general terms do not present high competitive ability against weed species due to the genetic refinement they were submitted to increase the occurrence of desired productive features in detriment of aggressiveness (Ainsworth and Rogers, 2007). Therefore, in theory, a good competitor could be the species with least resource requirement (Radosevich *et al.*, 2007).

In agricultural systems, both the crop and weeds grow together in the same area. As both groups usually demand similar environmental factors as water, light, nutrients and CO₂, and usually these resources are not enough even for the crops, the competition is established. Under this situation, any strange plant which emerges at this area will share these limited resources, causing a reduction both in the volume produced by the crops, as well as in the quality of the harvested product (Munch *et al.*, 2008). Radosevich *et al.* (2007) classified the environmental factors which determine plant growth in resources and conditions. Resources are the consumed factors such as water, CO₂, nutrients and light, and the response of plants usually follows a standard curve: it is small if the resource is less available and maximum at the saturation point, usually declining again in case of excessive availability of the resource (e.g. toxicity due to excessive zinc availability in the soil). Conditions are factors not directly consumed, such as P^H and soil density, although they influence directly plant ability in exploring the resources. However, plant competition will only be established when the demand of a given resource by a plant community surpasses the ability of the environment in supplying the demanded level of the given resource (Munch *et al.*, 2008).

2.3 Effects of weed competition on growth and yield of wheat

Weeds are plant which compete for nutrients, space, light and exerts lot of harmful effects by reducing the quality as well as quantity of the crop if the weed populations are left uncontrolled (Alemaw and Agegnehu , 2019).Weeds cause diseases in crops and support the insect pests. In agricultural term weeds are called pests because they cause damage to the crop. Weeds may reduce about 40-50% grain yield in wheat crop .Among the factors, which adversely affect the yield of wheat crop, weed infestation is the most harmful one but less

noticeable. Weeds comprise the most undesirable, aggressive and troublesome element of world's vegetation. Weeds are plants, which grow out of their proper places and whose virtue has not yet been discovered. Weeds also act as reservoir for multitude of pest and diseases, which use them as alternate hosts for food and shelter during the off season period. Weed density under both rained as well as irrigated conditions were studied for yield losses due to various densities of *Melilotus indica* L.(Oad *et al.*, 2007)

Wheat is attacked by different agricultural pests, but weeds remained the major problem play the main role. Weed losses in wheat may occur from initial stages to the last stage of maturity, harvest, threshing, winnowing and storing of wheat grains. Weed plants are more resistant, hardy and making faster growth than wheat and cause great growth and yield loss due to competition before crop harvest. Generally weeds reduce wheat yield by 30-50%. Losses may reach 100% depending on weed species and density (Tessema and Tanner, 1997). However, different workers reported different estimations of wheat yield losses depending on the infesting weed species, crop cultivar and their densities and the agricultural practices employed.

2.4 Critical period of crop-weed competition in wheat

Critical period of crop-weed competition (CPC) represents the time interval between two separately measured components; the maximum weed-infested period or the length of time that weeds which have emerged with the crop can remain before they begin to interfere with crop growth, and the minimum weed-free period or length of time a crop must be weed-free after planting in order to prevent yield loss. Competition may be interspecific between two or more plants belonging to different species of weeds or crops or intraspecific between plants of the same species which may be crop or weed species (Tana *et al.*, 2018). Weed competition is most serious when the crop is young and at active growth stage. It is essential in reducing weed control expenses. Weeds at this period must be removed by any mean or in economic language it is the shortest time span in the ontogeny of crop growth when weeding result in the highest economic returns. It is determined by crop species and cultivars, weed species and density, agricultural practices employed and prevailing environmental conditions.

Terefe *et al.* (2016) reported that the critical periods of weed competition in wheat ranges between 15-45 days after sowing (DAS) and also the critical weed competition period in wheat is 30 to 60 days after sowing. It occurs between 32 to 40 days after sowing and between 30-50 days after sowing (Chaudhary *et al.*, 2008). The critical period of weed-crop competition generally lies approximately between equal to the first one-third to one-half of the life cycle of the crop. Therefore, weeds that are present before or emerge after this period do not cause significant yield losses. Thus, crop yield obtained by weeding during critical period of weed competition is almost similar to that obtained by the full season weed-free conditions (Tana *et al.*, 2018).

2.5 Effects of seed rates on weed management and productivity of wheat

Optimum seeding rate is essential in determining the size of weed infestation in the field. This rate means ideal number of wheat plants per unit area that allow highest yield and smothering of weed. It is well established that yield increased with seeding rate up to a certain rate level after which no more increase obtained per plant basis while increasing rate per unit area is greatly decreased or kept steady or unchanged after certain plant density. The concept was termed as "the constant final yield". Optimum seeding rate minimize the space available between plants and rows which may be occupied by weeds. However, farmers should not exceed this rate in order to avoid any intraspecific competition effects of crop plants (Rao and Nagamani, 2010).

Planting fewer seeds may increase weed growth. Generally, high seeding rates should be increased when seeding is delayed beyond the optimum dates to compensate for reduced tillering (Shah *et al.*, 1994). Row spacing is in direct link with seeding rate and availability of water and nutrients. Under low soil moisture and fertility level planting distance between plants and rows may be increased to allow enough space to be exploited by individual crop plant. This however, opens the way for weed invasion and occupation of space available.

Weed control by hoe or herbicides should be implemented between rows. Wide rows associated with low seeding rate allows more crop tillering and facilitate mechanical weed control. Removed weeds vegetation may be laid into between rows (soil cover) to prevent any subsequent weed seed germination or growth. However, when moisture and nutrients are

unlimited, narrow rows and increased crop density offer advantages for weed control. Emerged weed seedling strongly suffered from both shading and competition effects of tall growing wheat plants. Narrow + row spacing can improve weed control during the fallow periods because weeds are smaller and more easily controlled with herbicides than they are in wide row (Derksen *et al.*, 2002).

Bhan *et al.* (1987) concluded that increasing seedling rate from 100 to 150 kg ha⁻¹ significantly reduced the dry matter of weeds and increased grain yield of wheat. Nazir *et al.* (1987) reported that 100 kg ha⁻¹ was the most effective in producing taller plants and higher yield as compared to low seedling rate. Mennan and Zandstra (2005) reported that decreasing the seeding rate from 250-200 kg ha⁻¹ decreased wheat yield in the presence of weed.

Sharma and Singh (2011) found that Weed population was significantly lower in crop sown at higher seed rates of 150 kg and 125 kg/ ha as compared to recommended seed rate of 100 kg seed/ha and lowest seed rate of 75 kg seed/ha though the differences between higher seed rates of 150 kg/ha and 125 kg/ha were statistically at par with each other. Increased plant density per unit area achieved by higher seed rates probably caused smothering of weeds and consequently reduced their dry matter. Further, successive increments of seed rate from 75 to 150 kg/ha significantly reduced dry matter accumulation of weeds. Seed rate of 150 kg/ha reduced 6.5, 13.6 and 30.3% in the first year and 3.2, 8.2 and 19.4% in the second year, dry matter of weeds compared to 125, 100 and 75 kg Seeds /ha, respectively.

Gill (2008) also observed that seed rate influenced the weeds dry matter effectively as the seed rates increased, the competition among crops increased which shows excellent smothering effect. Wheat seed rates significantly influenced grain and biomass yield, spike per unit area and kernel weight. Haile and Girma (2010) found that increasing seed rate over recommended (150 kg ha⁻¹) by 25 and 50% to 187.5 and 225 kg ha⁻¹ increased wild oat control efficacy by 16.9 and 21.5% respectively. Similarly, maximum weed control efficiency under 150 kg/ha seed rate and minimum under 75 kg/ha seed rate. Sharma and Singh (2011) concluded that sowing at 125 kg seed/ha with post-emergence application of sulfosulfuron at 25 g/ha at 30 DAS is the most economical and efficient weed management practice for

achieving high yield in wheat. Marwat *et al.* (2011) observed that integrating line sowing with higher seed rate (150 kg ha⁻¹) and herbicides (Buctril super) could suppress weeds.

2.6 Effects of herbicide application on weed management and productivity of wheat

Herbicides should be used in combination with good preventative, physical and cultural practices. A wide variety of herbicides are available for both annual grassy and broadleaf weed control in wheat. The effectiveness of the herbicide will depend upon a number of application and environmental factors. Most herbicides are recommended at a range of rates either to facilitate control of weeds in a window of growth stages or under differing densities. Weed control is always easier and less disruptive to the crop when done at an early growth stage on the weeds. Decreasing the water carrier volume can increase the danger of spray drift result in inadequate coverage of the weed species and cause yield damage. According to Tanner and Grief (1991) broadleaf herbicides in the first decade of research as the phenoxy compounds provided adequate control. Subsequent to the shift in the weed spectrum towards phenoxy-tolerant broadleaf species, broadleaf herbicide screening increased in the early 1980s.

On the other hand, reliance solely on chemical weed control involves excessive use of herbicides, resulting in pollution of the environment and inter and intra-specific shifts (Hassan and Marwat, 2001) due to the development of more competitive herbicide-resistant biotypes within a plant population or community (Shrestha *et al.*, 2010). In addition, herbicide use reduces N-uptake in wheat (Azad, 1997) leading to low growth and yields. This is especially true in the case of non-selective herbicides as reported by Malhi *et al.* (2007) who observed a significant reduction in plant N uptake in wheat by applying a mixture of non-selective (glyphosate) and selective (2,4-D) herbicides. For most infestations, the selective use of herbicides is necessary. However, the use of herbicides in conjunction with cultural and mechanical control methods usually result in the most effective management of weeds (Egan *et al.*, 1993).

Ahmad *et al.* (1993) observed that herbicides application decreased dry weight of weeds significantly compared to dry weight in non-treated plots. Chemical weed control in wheat was best in producing higher grain yield than hand weeding. Akhtar *et al.* (1991) found that

application of grassy and broad leaf herbicides increased grain yield and yield components of wheat.

Several investigations were made for the management of weeds in wheat fields. Studies on annual weeds control was done by many researchers in Ethiopia as well as outside the country. Accordingly, Dawit *et al.* (2014) was found that Pallas 45 OD had better weed control efficiency of broad spectrum especially for controlling serious weeds like *G. parviflora*, *G. scabra* and from grassy weeds *Avena fatua* L., *P. paradoxa* and *Phalaris minor* L. which were serious at Babicho and Faate. Move over, the highest weed suppression were from the combination of Pallas 45 OD with 2, 4-D and twice hand weeding followed by Derby +Pallas 45 OD and the highest was from weedy check and single herbicide application either for grass or broad leaf purposes (Zahara and Shigute,2017). The results of the present investigations we conclude that: annual weed species like *Amaranthus hybridus* L., *Argemon Mexicana* L., *Bindens pilosa* L., *Commelina benghalensis* L., *Datura stramonium* L., *G. parviflora*, *G. scabra*, *P. lanceolata* and *Xanthium strumarium* L. were highly managed by these sequential herbicides application (Zahara and Shigute,2017). Megersa *et al.* (2017) observed various weed species such as *G. scabra*, *P. nepalense*, *S. arvensis*, *R. raphanistrum*, *Achyranthes aspera*, *A. fatua* and *S. pumila* were effectively controlled by the application of Pallas 45 OD. It was also found that Pallas 45 OD decreased weed density by 79.8% and 81.8% at Shambo and Gedo, respectively. Pallas 45 OD was more effective on controlling broadleaved weeds which reduced the weed population as compared to 2, 4-D and also it can control serious grassy weeds on wheat (Bekele *et al.*, 2018). In addition to this, the application of 2, 4-D $EE\frac{1}{4} \text{ ha}^{-1} + \frac{1}{4} \text{ lha}^{-1}$ Pallas 45 OD has better herbicide efficacy could be the best option for weed management for wheat production. The grain yield of the Pyroxulam treatment was higher than the hand weeding treatment in all districts which could be due to the effectiveness of the herbicide in reducing weed competition at all stage of the crop. Wild oat control efficacy was varied highly among the herbicide rates and application timings. It was found that application of Topic 1 L ha^{-1} is more effective in controlling the target weed species.

3. MATERIALS AND METHODS

3.1 Description of the study area

Field experiment was conducted during the 2018/19 main cropping season under rain fed conditions at Holeta Agricultural Research Center. Holeta is located 33km west of Addis Ababa at an elevation of 2400 m.a.s.l and within the geographic coordinates of 9° 00'N and 38° 30'E. The area receives annual rain fall of 1144 mm with mean minimum and maximum temperatures of 6°C and 22°C respectively (EIAR,2018).The soil of the experimental field is clay loam with p^H of 6.65, organic carbon (2.26%), available Phosphorus (14.17 mg kg⁻¹),total nitrogen (0.12%)and cation exchange capacity of (17 Cmol kg⁻¹) (EIAR,2018).The edaphic and climatic conditions observed during the trial period were favorable for the exuberant growth of numerous weed species that competed with the crop plants. The climatic conditions observed during the trial period mean rain fall of 1114.5 mm relative humidity 78.8 % with mean minimum and maximum temperatures of 8°C and 25.2°C, respectively.

3.2 Experimental materials

The experimental materials used in the experiment were popular bread wheat variety *Dendea* and four types of broad leaf herbicides that were registered in Ethiopia for the control of annual broad leaf weeds (Table 2).

Table 2.Trade name, common names, rate and mode of action of herbicides used for study (MoANR, 2017).

Herbicides trade name	Common name	Rate ha ⁻¹	Mode of action (Spectrum of herbicides)
Agro 2,4 D 720 g/l	2,4-D	1L	Systemic herbicide for the control of broadleaf weeds in wheat, barley, teff, maize and sorghum
Pallas 45 OD	Pyroxulam	0.5L	Systemic herbicide for the control of grass weeds wild oat, downy brome (Bromus Spp.) and annual broadleaf weeds on wheat and tef.
Derby 175 SC	Florasulam	100ml	Systemic herbicide for the control of broadleaf weeds in cereals
Lancolet 450 WG	Florasulam +Aminopyrolid	33gm	Systemic herbicide for the control of broad leaf weeds in wheat.

3.3 Treatments and experimental design

The treatments (Table-3) included factorial combinations of three levels of seeding rates (100,150 and 200 kg ha⁻¹) and four types post emergence herbicides (Agro 2,4-D amine 720g/L ,Pallas 45 OD ,Derby 175 SC, Lancolet 450 WG plus weedy check .The experiment was laid out in a Randomized Complete Block Design with three replications.

Table 3.Treatment combinations of different levels of seed rates and herbicides

Herbicides(W)	Seed rates kg ha ⁻¹ (S)		
	100(S1)	150(S2)	200 (S3)
2,4 D 720 g/l(W1)	S1W1	S2W1	S3W1
Pallas 45 OD(W2)	S1W2	S2W2	S3W2
Derby 175 SC(W3)	S1W3	S2W3	S3W3
Lancolet 450 WG(W4)	S1W4	S2W4	S3W4
Weedy check(W5)	S1W5	S2W5	S3W5

3.4 Experimental procedure and crop management

The field was ploughed twice with tractor followed by harrowing to make fine seed bed. A 4 m x 3 m (12 m²) gross plot size was used as the experimental unit accommodating 15 rows of each 4 m length. Well popularized wheat variety, *Dendea* was used as a test crop. Seeds were drill planted in rows at 20 cm spacing between rows on July 17, 2018. The experimental area was fertilized with the recommended rate of 55 kg ha⁻¹ of N and 182 kg ha⁻¹ of P₂O₅ that were applied in the form of Urea (46% N) and DAP (18% N, 46% P₂O₅), respectively. Nitrogen fertilizer was applied at two doses (split application) i. e 2/3 of it was applied at time of sowing by mixing with full dose of Nitrogen and the remaining 1/3 was applied at tillering stage. Herbicides were applied at post emergence stage (30 DAE) with the help of knapsack sprayer nozzle size of 350um while the volume of water was 200L/ha⁻¹ pressurized at 40psi. All other management practices were uniformly applied to all plots as per the recommended practices.

3.5 Data collection

3.5.1 Weed parameters

Weed species identification was made by uprooting fresh weeds from experimental field and taken to laboratory. After the weed flora were identified, they were categorized as grasses and broad leaf weeds using reference of manuals, consulting experienced professionals and comparing with existed herbarium as described by Stroud and Parker (1989). Data regarding the kind of weed species and their densities were counted at 25 day after sowing i. e, before the application of herbicides by using four quadrats with sizes of 0.25 m x 0.25 m randomly placed in each plot and their density was calculated m⁻². In addition, individual weed species density count was also done at 25 and 45 days after herbicides were applied by randomly placing four quadrats of sizes 0.25m x 0.25m converted to m⁻². The density of each weed species in the field was counted after treatment by randomly placing of four quadrat of sizes 25 cm x25 cm in each plots and calculated m⁻² basis. The relative weed density was calculated by the formula (Marwat *et al.*, 2013):

$$RWD(\%) = \frac{\text{Number of weeds of a species}}{\text{total number of weeds}} \times 100$$
 The aboveground dry biomass of grass weeds and dry biomass of broad leaf weeds harvested from each quadrat placed into paper bags separately and oven drying at a 65 ° C for 48 hours and subsequently the dry weights were measured. Weed control efficiency (WCE) was determined by the following formula:

$$WCE(\%) = \frac{WDC - WDP}{WDC} \times 100$$
 Where, WCE=Weed Control Efficiency, WDC=Weed Dry weight in Control Plot and WDP = Weed Dry weight in Particular treatment (Davasenapathy *et al.*, 2008).

3.5.2 Crop parameters

3.5.2.1 Crop phenological parameter

Days to heading: It was recorded as the number of days from sowing to the day when plants reached heading based on visual observation.

3.5.2.2 Growth parameters

Plant height (cm): It was taken with a meter from 4 randomly taken and pre-tagged plants in each net plot area from the plant base to the tip of the spike excluding of awns at physiological maturity and the average was used for the analysis.

Spike length (cm): It was taken with a ruler from 4 randomly taken and pre-tagged plants in each net plot area from the base of the spike to the tip of the spike excluding of awns at physiological maturity and the average was used for the analysis.

3.5.2.3 Yield and yield components

Number of fertile tillers: The numbers of total productive tillers counted from five rows with the length of 1 m randomly taken in each net plot area and was converted into m² at harvest.

Number of seeds per spike: The number of seeds per spike was determined from randomly taken 4 spikes per plot.

Thousand grain weights (g): Thousand grains weight was counted from the bulk of threshed produce from the net plot area and their weight recorded.

Biological yield (kg ha⁻¹): biological yield (kg ha⁻¹) was determined by taking the total weight of the harvest from each net plot area after sun dried the whole aboveground biomass.

Grain yield (kg ha⁻¹): It was measured after threshing the sun dried plants harvested from each net plot and the yield was adjusted at 12.5% grain moisture content (Amare *et al.*, 2014).

Harvest index (%): Harvest index was calculated by dividing grain yield per plot by the total aboveground dry biomass yield per plot (Amare *et al.*, 2014; Tana *et al.*, 2018)

$$HI(\%) = \frac{\text{Grain yield}}{\text{Total above ground biomass}} \times 100$$

Yield loss (%): It was calculated by subtraction of grain yield of particular treatment from maximum grain yield from treatments divided by maximum grain yield from treatments (Amare *et al.*, 2014).

$$YL(\%) = \frac{\text{Maximum grain yield from treatment} - \text{Grain yield of particular treatment}}{\text{Maximum grain yield from treatment}} \times 100$$

3.6 Statistical analysis

The means of each data was checked by the normality test depending on Shapiro test ($P < W$) before analysis of variance using the GLM procedure of SAS (SAS 9.3 version). When the treatment effects were significant, means were compared using Fisher's LSD test at 5% level of significance (Gomez and Gomez, 1984). Correlations between traits were also analyzed using Pearson's correlation coefficients in SAS (Gomez and Gomez, 1984).

3.7 Partial budget analysis

The partial budget analysis was made to determine the economic feasibility of the treatments. It was calculated by taking into account the variable input cost involved and the gross returns obtained from different treatments. The variable cost included the fertilizers, herbicides, seed, labor cost involved for harvesting, threshing and winnowing as their cost varied according to

the time, availability of labor and the market price. Actual yield was adjusted downwards to 10% of the experimental yield to represent the farmer's yield as described by CIMMYT(1988). For determining gross returns, the prevailing local market price Ethiopian birr 1400 /100 kg of wheat at the harvest of wheat was considered. The net returns were calculated by subtracting the cost of treatment from the gross returns as $RNR = GR - VC$, where, RNR = Relative net returns, GR = Gross returns, and VC = Variable cost. Benefit to cost ratio was calculated by dividing gross return to total variable cost. The marginal rate of return was calculated by the formula $MRR = \frac{DNI}{DIC}$, Where, MRR = the marginal rate of return, DNI = difference in net income compared with control and DIC = difference in input cost compared with control as described by CIMMYT (1988).

4. RESULTS AND DISCUSSION

4.1 Weed parameters

4.1.1 Composition of weed flora and density in the experimental field

The weed community comprised of both broadleaf and grass weeds which were classified in to eight major families. Out of total weeds species present in the experimental field 86 % were annual broadleaf weeds while 14% were annual grasses weeds. The maximum relative weed density in the field was *G. pulviflora* (22.84%) followed by *P. nepalense* (18.72%) while minimum relative weed density was recorded from *G. scabra* (0.98%) (Table - 4).

Table 4. Categories of the identified weed species and their densities in the experimental field

Scientific names	Families	Weed density m ⁻² before spray	Relative Weed Density (%)	Life form/category
<i>Arthraxon prinodes</i> L.	Poaceae	21.06	5.11	Annual (grass)
<i>Setaria pumila</i> L.	Poaceae	31.33	7.59	Annual (grass)
<i>Phalaris paradoxa</i> L.	Poaceae	5.39	1.31	Annual (grass)
<i>Galinsoga pulviflora</i> Cav.	Compositae	94.18	22.84	Annual (broad leaf)
<i>Corrigiola capensis</i> Wild	Caryophyllaceae	48.71	11.81	Annual (broad leaf)
<i>Guizotia scabra</i> (Vis)Chiov	Compositae	4.06	0.98	Annual (broad leaf)
<i>Oxalis corniculata</i> HBK	Oxalidaceae	28	6.77	Annual (broad leaf)
<i>Plantago lanceolata</i> L.	Plantaginaceae	19.1	4.62	Annual (broad leaf)
<i>Polygonum nepalense</i> L.	Polygonaceae	77.2	18.72	Annual (broad leaf)
<i>Raphanus raphanistrum</i> L.	Brassicaceae	15.5	3.76	Annual (broad leaf)
<i>Spergula arvensis</i> L.	Caryophyllaceae	20	4.85	Annual (broad leaf)
<i>Cyanotis barbata</i> D.Don	Commelinaceae	47.7	11.57	Annual (broad leaf)

The result indicated that variation of weed flora composition could be depending on amount of weed seed bank in the soil, germination capacity and favorable environmental conditions. Abraham (2006) also reported that weed growth, population density and distributions in cereal fields vary from place to place depending upon soil and climatic factors and management practices.

4.1.2 Effects of seed rates and herbicides application on weed densities after application

The main effects of seed rates, herbicides and their interaction was significant on density of *P. nepalense* after herbicides application (Appendix Table-1). Minimum weeds density 2.48 m⁻² of *P. nepalense* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with all herbicides except Pallas 45 OD statistically showed that no significant as well as the application of 150 kg ha⁻¹ seed rate with all herbicides except Lancolet 450 WG caused no significant difference. Moreover, the combined effects of 200 kg ha⁻¹ with Derby 175 SC and Lancolet 450WG showed no significant difference.

The main effects of seed rates, herbicides and their interaction on density of *R. raphanistrum* was significant on weed density after herbicides application (Appendix Table-1). Minimum weeds density 2.46 m⁻² of *R. raphanistrum* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The interaction effects of 100 kg ha⁻¹ with all herbicides revealed that statistically no significant difference except Pallas 45 OD and also the interaction effects of 150 kg ha⁻¹ seed rate with all herbicides except for Lancolet 450 WG revealed that statistically no significant difference. Furthermore, the interaction of 200 kg ha⁻¹ seed rate with 2, 4-D and Pallas 45 OD caused no significant difference. Correspondingly, the application of 200 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG caused no significant difference.

The main effect of seed rates, herbicides and their interaction was significant on density of *P. lanceolata* after herbicides application (Appendix Table-1). Minimum weeds density 2.5 m⁻² of *P. lanceolata* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with all herbicides except Pallas 45 OD resulted no significant difference and also the interaction effects of 150 kg ha⁻¹ seed rate with the combination of 200 kg ha⁻¹ seed rate with 2,4-D and Derby 175 SC caused statistically no

significant difference. Similarly, the application of 200 kg ha⁻¹ seed rate with Pallas 45 OD and Lancolet 450 WG caused no significant difference.

The main effect of seed rates, herbicides and their interaction was significant on density of *C. barbata* after herbicides application (Appendix Table-1). Minimum weeds density 3.05 m⁻² of *C. barbata* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with all herbicides application showed that statistically no significant difference. Similarly, the application of 150 kg ha⁻¹ seed rate with 2,4 -D and Pallas 45 OD showed that no significant difference. Moreover, the application of 150 kg ha⁻¹ seed rate with Derby and Lancolet 450 WG caused no significant difference. Moreover, the application of 200 kg ha⁻¹ seed rate with all herbicides except 2, 4-D caused no significant difference.

The main effect of seed rates, herbicides and their interaction was significant on density of *C. capensis* after herbicides application (Appendix Table-1). Minimum weeds density 3.1 m⁻² of *C. capensis* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG showed that no significant difference. Similarly, the application of 150 kg ha⁻¹ seed rate with 2, 4-D and Lancolet showed that no significant difference. Moreover, the application of 150 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC caused statistically no significant difference. The application of 200 kg ha⁻¹ seed rate with all herbicides except 2, 4-D and Lancolet 450 WG caused statistically no significant difference. Similarly, the application of 200 kg ha⁻¹ with Pallas 45 OD and Derby 175 SC resulted no significant difference.

Table 5. The effect of seed rates and herbicides on individual weed densities after application

Treatments	<i>Polygonum nepaense</i> L.	<i>Raphanus raphanistrum</i> L.	<i>Plantago lanceolata</i> L.	<i>Cyanotis barbata</i> D.Don	<i>Corrigiola capensis</i> Wid.	<i>Spergula arvensis</i> L.	<i>Galinsoga pulviflora</i> Cav.	<i>Arthraxon prinodes</i> L.	<i>Guizotia scabra</i> (Vis) Chiov	<i>Setaria pumila</i> L.	<i>Phalaris paradoxa</i> L.	<i>Oxalis corniculata</i> HBK.
S ₁ *W ₁	3.33 ^{cd}	3.18 ^{cde}	3.29 ^{bc}	3.83 ^{bc}	3.75 ^d	3.66 ^d	3.7 ^{cd}	3.71 ^{bc}	3.65 ^c	2.43 ^c	2.41 ^c	3.68 ^{bc}
S ₁ *W ₂	2.86 ^{def}	2.81 ^{ef}	3.18 ^{bcd}	3.85 ^b	3.21 ^f	3.2 ^g	3.25 ^{fg}	3.7 ^{bc}	3.29 ^f	2.16 ^{cde}	2.06 ^{cde}	3.25 ^f
S ₁ *W ₃	3.56 ^c	3.5 ^c	3.43 ^b	3.75 ^{bc}	3.5 ^e	3.51 ^e	3.48 ^{de}	3.46 ^{cdef}	3.36 ^{ef}	2.3 ^{cd}	2.41 ^c	3.48 ^{de}
S ₁ *W ₄	3.3 ^{cde}	3.36 ^c	2.83 ^{cde}	3.51 ^{bcd}	3.65 ^e	3.63 ^e	3.62 ^{de}	3.58 ^{bc}	3.56 ^{cde}	2.13 ^{cde}	2.16 ^{cde}	3.6 ^{cd}
S ₁ *W ₅	5.16 ^a	2.76 ^{ef}	4.55 ^a	4.95 ^a	4.36 ^a	4.4 ^a	4.58 ^a	4.63 ^a	4.61 ^a	3.91 ^a	3.95 ^a	4.41 ^a
S ₂ *W ₁	2.75 ^{fg}	2.76 ^{ef}	3.18 ^{bcd}	2.88 ^f	3.68 ^d	3.61 ^e	3.63 ^{de}	3.62 ^{bcd}	3.38 ^{def}	2.08 ^{cde}	2.08 ^{cde}	3.61 ^{cd}
S ₂ *W ₂	2.48 ^g	2.46 ^f	2.5 ^e	3.05 ^{ef}	3.1 ^f	3.18 ^g	3.11 ^g	3.25 ^{ef}	3.22 ^f	1.41 ^{fgh}	1.41 ^{fg}	3.2 ^f
S ₂ *W ₃	2.78 ^{fg}	2.76 ^{ef}	2.75 ^{de}	3.41 ^{cde}	3.21 ^f	3.21 ^g	3.24 ^{fg}	3.19 ^{bcd}	3.25 ^f	1.88 ^{de}	2.03 ^{cde}	3.29 ^{ef}
S ₂ *W ₄	3.25 ^{cdef}	3.19 ^{cde}	3.01 ^{bcd}	3.21 ^{def}	3.63 ^e	3.58 ^e	3.62 ^{de}	3.56 ^{bcd}	3.54 ^{cde}	1.78 ^{efg}	1.78 ^{def}	3.46 ^{de}
S ₂ *W ₅	4.66 ^{ab}	4.61 ^b	4.23 ^a	3.91 ^b	4.13 ^b	4.16 ^b	4.2 ^b	4.3 ^a	4.38 ^a	3.83 ^{ab}	3.66 ^{ab}	4.26 ^a
S ₃ *W ₁	2.81 ^{efg}	2.86 ^{def}	3.34 ^{bc}	3.51 ^{bcd}	3.48 ^e	3.46 ^{ef}	3.7 ^{cd}	3.56 ^{bc}	3.61 ^{cd}	1.86 ^{def}	1.73 ^{def}	3.54 ^{cd}
S ₃ *W ₂	2.53 ^g	2.53 ^f	2.68 ^{de}	3.08 ^{ef}	3.23 ^f	3.3 ^{fg}	3.24 ^{fg}	3.34 ^{cdef}	3.22 ^f	1.16 ^h	1.1 ^g	3.31 ^{ef}
S ₃ *W ₃	3.32 ^{cde}	3.3 ^{cd}	3.4 ^b	3.2 ^{def}	3.21 ^f	3.25 ^g	3.23 ^{fg}	3.26 ^{def}	3.22 ^f	1.38 ^{gh}	1.71 ^{ef}	3.23 ^f
S ₃ *W ₄	3.15 ^{cde}	3.16 ^{cde}	2.96 ^{bcd}	3.25 ^{def}	3.48 ^e	3.45 ^{ef}	3.45 ^{ef}	3.42 ^{cdef}	3.37 ^{ef}	2.11 ^{cde}	2.21 ^{cd}	3.34 ^{ef}
S ₃ *W ₅	4.5 ^b	4.5 ^a	4.18 ^a	3.86 ^b	3.86 ^c	3.88 ^c	3.88 ^c	3.9 ^b	3.9 ^b	3.41 ^b	3.41 ^b	3.86 ^b
LSD(5)	0.5	0.46	0.54	0.43	0.17	0.18	0.22	0.37	0.23	0.45	0.48	0.19
CV%	8.97	8.34	9.91	7.28	2.9	3.14	3.69	6.1	3.92	11.96	12.86	3.21

Means followed by the same letter in the lower case with in columns are not significantly different from each other at 5% level of significance. S₁=100 kg ha⁻¹, S₂=150 kg ha⁻¹, S₃=200kg ha⁻¹, W₁=Agro 2, 4-D amine 720g/L, W₂=Pallas 45 OD, W₃=Derby 175 SC, W₄= Lancolet 450 WG and W₅= weedy check

The main effect of seed rates, herbicides and their interaction was significant on density of *S.arvensis* after herbicides application (Appendix Table-1). Minimum weeds density 3.18 m⁻²

of *S. arvensis* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with all herbicides except with Pallas 45 OD showed that no significant difference. Similarly, the application of 150 kg ha⁻¹ seed rate with 2,4-D and Lancolet 450 WG showed that no significant difference. Moreover, the application of 150 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC caused no significant difference. The application of 200 kg ha⁻¹ seed rate with all herbicides except 2, 4- D and Lancolet 450 WG caused no significant effects. Similarly, the application of 200 kg ha⁻¹ with Pallas 45 OD and Derby 175 SC resulted no significant difference.

The main effect of seed rates, herbicides and their interaction was significant on density of *G. pulviflora* after herbicides application (Appendix Table-1). Minimum weeds density 3.11 m⁻² of *G. pulviflora* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with all herbicides except with Pallas 45 OD showed that no significant difference on. Similarly, the application of 150 kg ha⁻¹ seed rate with 2,4 -D and Lancolet showed that no significant difference. Moreover, the application of 150 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC caused no significant difference. Similarly, the application of 200 kg ha⁻¹ with Pallas 45 OD and Derby 175 SC resulted no significant difference.

The main effect of seed rates, herbicides and their interaction was significant on density of *A. prinodes* after herbicides application (Appendix Table-1). Minimum weeds density 3.25 m⁻² of *A. prinodes* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with all herbicides except for weedy check showed that no significant difference. Correspondingly, the application of 150 kg ha all herbicides except Pallas 45 OD showed that no significant difference. Moreover, the application of 200 kg ha⁻¹ seed rate with all herbicides except 2, 4-D caused no significant difference.

The main effect of seed rates, herbicides and their interaction was significant on density of *G. scabra* after herbicides application (Appendix Table-1). Minimum weeds density 3.22 m⁻² of *G. scabra* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with 2,4- D and Lancolet 450 WG showed that no significant difference. Similarly, the application of 100 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC showed that no significant difference. Moreover, the application of 150 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC caused no significant difference. Correspondingly, the application of 150 kg ha⁻¹ seed rate with 2, 4-D and Lancolet 450 WG showed that no significant difference. The application of 200 kg ha⁻¹ seed rate with all herbicides except 2, 4-D showed that no significant difference.

The main effects of seed rates, herbicides and their interaction was significant on density of *S. pumila* after herbicides application (Appendix Table-1). Minimum weeds density 1.16 m⁻² of *S. pumila* was recorded from interaction of 200 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from interaction of 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with all herbicides except for weedy check showed that no significant difference. Similarly, the application of 150 kg ha⁻¹ seed rate with all herbicides except Pallas 45 OD showed that no significant difference. Moreover, the application of 200 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC caused no significant difference. Similarly, the application of 200 kg ha⁻¹ with Pallas 45 OD and Derby 175 SC resulted no significant difference.

The main effect of seed rates, herbicides and their interaction was significant on density of *P. paradoxa* after herbicides application (Appendix Table-1). Minimum weeds density 1.1m⁻² of *P. paradoxa* was recorded from interaction of 200 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with all herbicides except for weedy check showed that no significant difference. Similarly, the application of 150 kg ha⁻¹ seed rate with all herbicides except Pallas 45 OD showed that no significant difference. Moreover, the application of 200 kg ha⁻¹ seed rate with 2, 4-D and Derby 175 SC caused no significant difference.

The main effect of seed rates, herbicides and their interaction was significant on weed density after herbicides application (Appendix Table-1). Minimum weeds density 3.2 m⁻² of *O. corniculata* was recorded from interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the maximum number was obtained from 100 kg ha⁻¹ seed rate at weedy check (Table-5). The application of 100 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG showed that no significant difference. Similarly, the application of 150 kg ha⁻¹ seed rate with 2, 4-D and Lancolet 450 WG showed that no significant difference. Moreover, the application of 150 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC caused statistically no significant difference. Moreover, the application of 200 kg ha⁻¹ with all except 2, 4-D resulted no significant difference.

The result revealed that the application of different levels of seed rates with combination of broad spectrum herbicides resulted in decreased weed density per unit area due to limited availability for space consequently resulted decreased growth. The herbicides were also persistent enough and caused the mortality of weeds by affecting the physiological processes.

These results are in line with work of Bibi *et al.* (2008) who concluded that herbicides significantly affected the weed population per unit area when applied at post-emergence stage of wheat crop.

4.1.3 The effects of seed rates and herbicides on weed density at 25 and 45 days after herbicides application in bread wheat

The application of different levels seed rates and the interaction showed that significant effect on weeds density m⁻² at 25 DAP while application of herbicides had no significant effect on weed density (Appendix Table - 2). Minimum weeds density (4.52 m⁻²) was recorded from interaction of 150kg ha⁻¹ seed rate with Pallas 45 OD whereas maximum weeds density m⁻² was recorded in weedy check plots at all interactions (Table - 6).

This result revealed that there is no statistically significant difference was observed with interaction effects of 2, 4 - D and Pallas 45 OD along with all seed rates. Similarly, the application of 150 kg ha⁻¹ and 200 kg ha⁻¹ seed rates with Derby 175 SC and Lancolet 450

WG caused statistically no significant difference. Moreover, the application of all seed rates with all herbicides revealed that statistically no significant difference except for weedy checks.

The interaction of increased seed rates 150 kg ha⁻¹ in combination with Pallas 45 OD resulted in lower weed density than other interactions could be related to less intra specific competition due to minimum plant density that created better growing condition for weed than crop and the herbicides were not persistent enough to kill growing weeds.

Table 6. The effects of seed rates and herbicides on weed density m⁻² at 25 and 45 days after herbicides application in bread wheat

Herbicides	Weed density 25 DAP		
	Seed rates kg ha ⁻¹		
	100	150	200
2,4- D 720 g/l	4.9 ^{DeF}	4.68 ^{EF}	4.64 ^{EF}
Pallas 45 OD	4.88 ^{deF}	4.52 ^F	4.65 ^{eF}
Derby 175 SC	5.16 ^{cd}	4.68 ^{eF}	4.53 ^F
Lancolet	5.03 ^{cde}	4.92 ^{deF}	4.58 ^F
+Weedy check	6.05 ^a	5.68 ^{ab}	5.42 ^{bc}
LSD (1%)	0.43		
CV(%)	5.25		
	Weed density 45 DAP		
2,4 - D 720 g/l	3.38 ^{de}	2.88 ^{Ghi}	3.13 ^{efG}
Pallas 45 OD	3.05 ^{fg}	2.7 ^I	2.74 ^{HI}
Derby 175 SC	3.31 ^{def}	2.92 ^{GHi}	2.98 ^{GH}
Lancolet	3.24 ^{def}	3.41 ^d	3.12 ^{fg}
Weedy check	4.56 ^a	4.2 ^b	3.93 ^c
LSD (1%)	0.26		
CV (%)	4.76		

Means followed by the same letter in the upper case with in rows and lower case with in columns are not significantly different from each other at 1% level of significance

However, for better weed control the effectiveness of tested herbicides could be more than 25 days of application. Similar results were reported from Bibi *et al.* (2008) who concluded that herbicides significantly affected the weed population per unit area when applied at post emergence stage of wheat crop.

The main effects of seed rates and herbicides application as well as their interaction were significant on weed density at 45 DAP (AppendixTable - 2).The combined effects of 150 kg ha⁻¹ seed rate with pallas 45 OD showed that lowest weed density (2.7m⁻²) as compared to any other treatments, whereas the highest weed density count (4.56m⁻²) was recorded from the interaction of 100 kg ha⁻¹seed rate at weedy check plots (Table - 6).The application of 100 kg ha⁻¹ seed rate with all herbicides except Pallas 45 OD showed that statistically non-significant and also application of 150 kg ha⁻¹ seed rate with 2,4 - D and Derby 175 SC revealed that statistically no significant difference. Similarly, application of 200 kg ha⁻¹ seed rate with 2, 4 - D and Lancolet 450 WG revealed that statistically no significant difference. Moreover, the application of 200 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC revealed that statistically no significant difference. In addition, the application of all herbicides except Lancolet 450 WG with increased seed rates from 100 kg ha⁻¹ to 200 kg ha⁻¹ showed that statistically no significant difference.

The result clearly indicated that application of 150 kg ha⁻¹ seed rate with Pallas 45 OD decreased weed density at 45 days of application. This might be related to lower inter and intra specific competition and herbicides were persistent enough to suppress weeds up to 45 days after treatment and beyond that. Thus, the lack of competition with weeds enabled wheat to close its canopy and dominate weeds throughout the growing season. These results are in line with those of Bibi *et al.* (2008) who concluded that herbicides significantly affected the weed population per unit area.

4.1.4 Effects of seed rates and herbicides application on weed dry weight at harvest

4.1.4.1 Dry biomass of broad leaf weeds at harvest

The main effects of seed rates, herbicides application and their interaction were significant on dry biomass of broad leaf weeds (AppendixTable-2).The highest dry biomass of broad leaf weeds (490 kg ha⁻¹) was recorded in weedy check at 100 kg ha⁻¹ seed rate whereas the minimum (46.67 kg ha⁻¹) was recorded in combination of 200kg ha⁻¹ seed rate with Pallas 45 OD application (Table-7).

The application of all herbicides with 150 kg ha⁻¹ and 200 kg ha⁻¹ seed rates revealed that statistically no significant difference. Similarly, the application of 100 kg ha⁻¹ seed rate with all herbicides except Pallas 45 OD produced statistically no significant difference. The minimum dry biomass of broad leaf weeds at 200 kg ha⁻¹ seed rate with Pallas 45 OD might be related to the activity of the treatments higher seed rate with broad spectrum herbicides that resulted in less inter and intra-specific competition and also due to the ability of the herbicide in reducing weed density by killing both broadleaf and narrow leaf weeds by affecting the physiological process of those weeds resulted in mortality of weeds that remained in field.

Table 7.The effect of seed rates and herbicides application on dry biomass of broad leaf weeds (kg ha⁻¹) in bread wheat

Herbicides	Seed rates kg ha ⁻¹		
	100	150	200
2,4 D 720 g/l	105 ^d	75 ^{eF}	65 ^{Fgh}
Pallas 45 OD	61.67 ^F	65 ^{Fgh}	46.67 ^h
Derby 175 SC	98.33 ^d	71.67 ^{eFG}	63.33 ^h
Lancolet 450 WG	88.33 ^{de}	63.33 ^{fgh}	53.33 ^{gh}
Weedy check	490 ^a	413.33 ^b	358.33 ^c
LSD (1%)	8.97		
CV(%)	8.97		

Means followed by the same letter in the upper case with in the rows and lower case with in the columns are not significantly different from each other at 1% level of significance

This result also indicated that the combined use of higher seed rate decreased the growth of weeds by covering the available spaces and resulted in limited weed growth. The lower number of dry weed biomass related to ability of herbicide acting on many broad leaf weed species and also due to minimum number of weed density but the higher number dry broad weed at weedy check could be better higher weed growth .This finding was analogous with Tana *et al.*(2018) who concluded that the weed dry weight recorded in weed-free treatments of longer duration was reduced than weedy treatments due to the reason that temperature and climatic requirements were not in favor of weed seed germination after the first weeds were removed.

4.1.4.2 Dry biomass of grass weeds at harvest

The effect of seed rates, herbicides and their interactions were highly influenced by dry biomass of grass weeds (Appendix Table-2). The interaction of Pallas 45 OD with 150 kg ha⁻¹ seed rate gave minimum grass weed biomass (33.33 kg ha⁻¹) followed by interaction of Lancolet 450 WG with 200 kg ha⁻¹ seed rate (41.66 kg ha⁻¹). The highest dry weight of grass weed (66.66 kg ha⁻¹) was obtained from the interaction of 100 kg ha⁻¹ and 150 kg ha⁻¹ seed rates at weedy check (Table -8).

Table 8. The effects seed rates and herbicides on dry biomass of grass weeds (kg ha⁻¹) in bread wheat

Herbicides	Seed rates kg ha ⁻¹		
	100	150	200
2,4 D 720 g/l	53.33 ^{Bc}	45 ^{Cd}	48.33 ^{bCd}
Pallas 45 OD	48.33 ^{bcD}	33.33 ^E	41.66 ^{dE}
Derby 175 SC	53.33 ^{bc}	45 ^{CD}	45 ^{CD}
Lancolet 450WG	55 ^{bc}	45 ^{CD}	41.66 ^{De}
Weedy check	66.66 ^A	66.66 ^A	56.66 ^{Ab}
LSD (1%)	10.39		
CV(%)	12.55		

Means followed by the same letter in the upper case with in the rows and lower case with in columns are not significantly different from each other at 1% level of significance

The interaction of 100 kg ha⁻¹ and 200 kg ha⁻¹ seed rates with all herbicides except for weedy check statistically showed that no significant difference and also the application of 150 kg ha⁻¹ seed rate with all herbicides except application with Pallas 45 OD showed that statistically no significant difference. The application of all seed rate with 2,4-D, Derby 175 SC and Lancolet 450 WG produced statistically no significant difference. The lowest number of dry biomass of grass weeds at 150 kg ha⁻¹ seed rate with Pallas 45 OD due to reducing the density of weeds and also suppressed the weed growth consequently resulted in lower dry weight. Lower weed dry weight in plots where herbicides were applied can be attributed to low weed density.

This finding was similarly with Nadeem *et al.*(2006) and Munsif *et al.*(2009) who concluded that maximum weed density in weedy check can be attributed to unchecked growth, while application of herbicide caused mortality of weed resulting in lower weed density at harvest.

Unavailability of nutrients in control and suppression by well-developed wheat plants resulted in similar weed density.

4.1.5 Weed control Efficiency

Weed control efficiency was influenced by seed rates, herbicides application and their interactions (AppendixTable-2).The maximum weed control efficiency was recorded in the interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD (81.22%) followed by 200 kg ha⁻¹ seed rate with Pallas 45 OD (78.6%) (Table - 9).

Table 9.The effects seed rates and herbicides on weed control efficiency (%) in bread wheat

Herbicides	Seed rates kg ha ⁻¹		
	100	150	200
Agro2,4 –D 720 g/l	71.58 ^E	74.44 ^{bcdE}	72.55 ^{dE}
Pallas 45 OD	77.46 ^{Abc}	81.22 ^A	78.6 ^{Ab}
Derby 175 SC	72.64 ^{DE}	75.15 ^{bcDE}	73.76 ^{cDE}
Lancolet 450WG	72.45 ^{de}	76.92 ^{abCD}	76.66 ^{abCD}
Weedy check	0.00 ^F	0.00 ^F	1.93 ^F
LSD (1%) interactions=4.72			
CV (%) interactions=4.68			

Means followed by the same letter in the uppercase with in rows and the same letter in the lower case with in columns are not significantly different from each other at 1% level of significance

The application of all seed rates with all herbicides except Pallas 45 OD showed that statistically no significant difference. Similarly, the application of 200 kg ha⁻¹ seed rate with 2, 4-D, Derby 175 SC and Lancolet 450WG revealed that statistically no significant difference. Furthermore, the interaction of increased seed rate 100 kg ha⁻¹ to 200 kg ha⁻¹ with all herbicides application showed that statistically no significant difference except for weed check. The higher weed control efficiency at higher seed rate with Pallas 45 OD might be related to lowest dry biomass of weeds which exhibited that the ability of the herbicides killing various weeds species in wheat.

Additionally, the result also revealed that increased seed rate with combination of broad spectrum herbicides increased weed control efficiency due to limited weed growth but at low

seed rate decreased in weed control efficiency as a result of severe inter and intra specific competition and higher weed biomass. The use of Pallas 45 OD increased weed control efficiency at all seed rate interaction. This might be related to the activity of broad spectrum of the herbicide against both broad and grassy weeds as compared to other herbicides application. These findings are similar with who reported that herbicides with broad spectrum provided better weed control efficiency than control treatment (Ashiq *et al.*,2007).Tana *et al.* (2018) reported that the high control efficiency indicated that the weed were controlled when they are young or before they accumulated more dry matter by competing with the crop plants.

4.2 Days to heading

Days to heading was influenced by herbicides application and their interactions but not significantly influenced by the application of different levels of seed rates (AppendixTable-3).The maximum days to heading was recorded in the interaction of 100 kg ha⁻¹ seed rate with weedy check (83.33) followed by 200 kg ha⁻¹ seed rate with weedy check (81.66) (Table - 10).

Table 10.The effects seed rates and herbicides on days to heading in bread wheat

Herbicides	Seed rates kg ha ⁻¹		
	100	150	200
Agro2,4 –D 720 g/l	73.33 ^c	71.66 ^c	71.66 ^c
Pallas 45 OD	71.66 ^c	73.33 ^c	71.66 ^c
Derby 175 SC	76.66 ^c	75 ^c	71.66 ^c
Lancolet 450WG	75 ^c	73.33 ^c	71.66 ^c
Weedy check	83.33 ^a	76.66 ^{bc}	81.66 ^{ab}
LSD (5%)	6.21		
CV (%)	4.99		

Means followed by the same letter in the lower case with in columns and rows are not significantly different from each other at 5% level of significance

The application of 100 kg ha⁻¹ seed rate with all herbicides revealed that statistically no significant difference except for weedy check and also the application of 200 kg ha⁻¹ seed rate

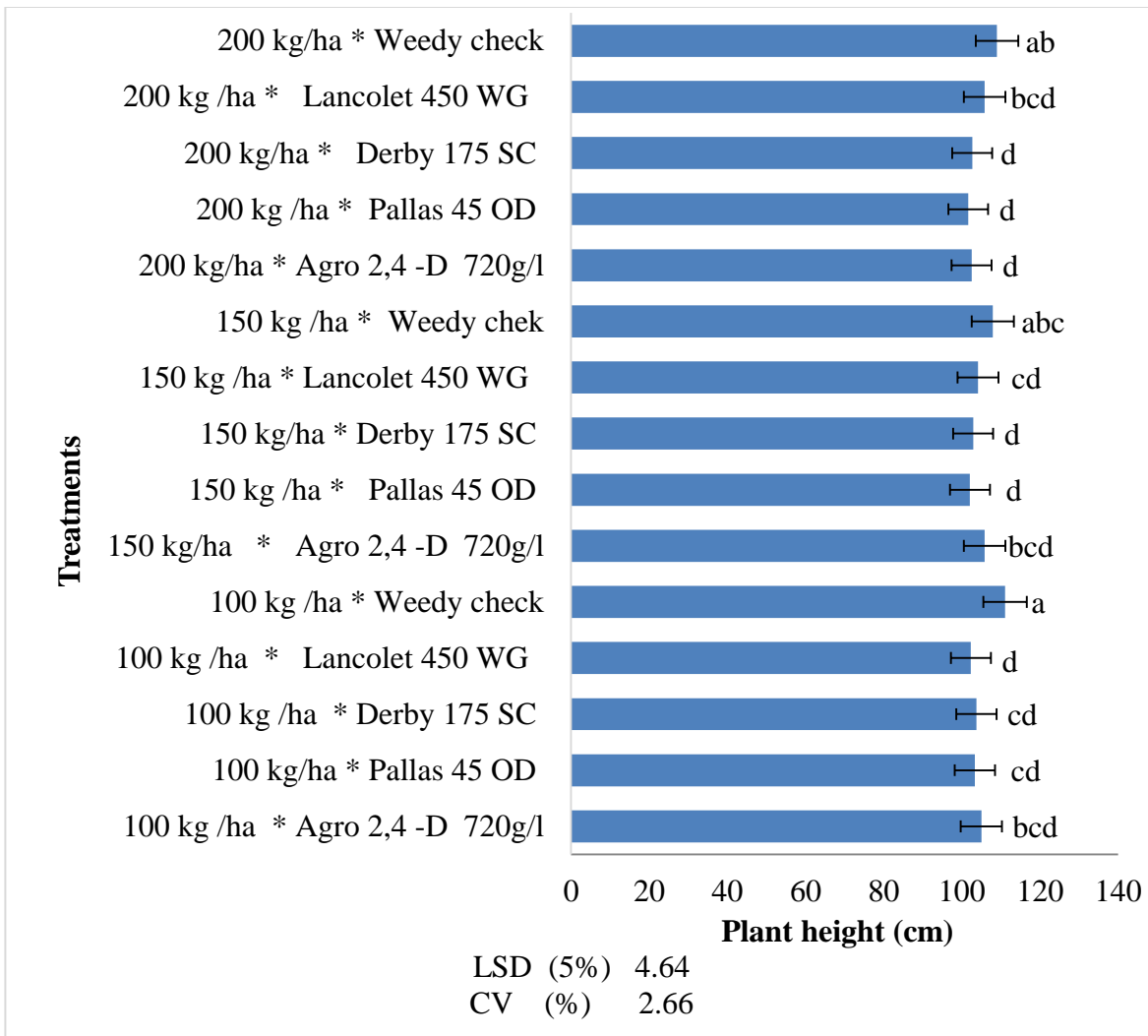
with all herbicides revealed that statistically no significant difference except for weedy check. Furthermore, the application of all herbicides with increased seed rate 100 kg ha⁻¹ to 200 kg ha⁻¹ caused statistically no significant difference. The result revealed that earlier days to heading might be due to minimum crop weed competition. The delay in days to heading in weedy checks was probably due to severe competition for resources and also shading effects of weeds over crop for utilizing light. Tana *et al.* (2018) stated that no significant variation in days to heading due to the same variety used in the study.

4.3 Crop growth parameters

4.3.1 Effects of seed rates and herbicides application on growth of wheat

4.3.1.1 Plant height

The main effects of seed rates and tested herbicides had no significant effect on plant height but the interaction of seed rates with herbicides brought significant effect on plant height (AppendixTable -3).The maximum plant height was obtained from the interaction of 100 kg ha⁻¹ seed rates at weedy check plots(111.08 cm) followed by 200 kg ha⁻¹ seed rate with weedy check(109cm) while the minimum plant height(101.66cm) was obtained from the interaction effects of 200kg ha⁻¹ seed rate with pallas 45 OD (Figure 1).



Means followed by the same letter in the lower case with in column chart are not significantly different from each other at 5% level of significance

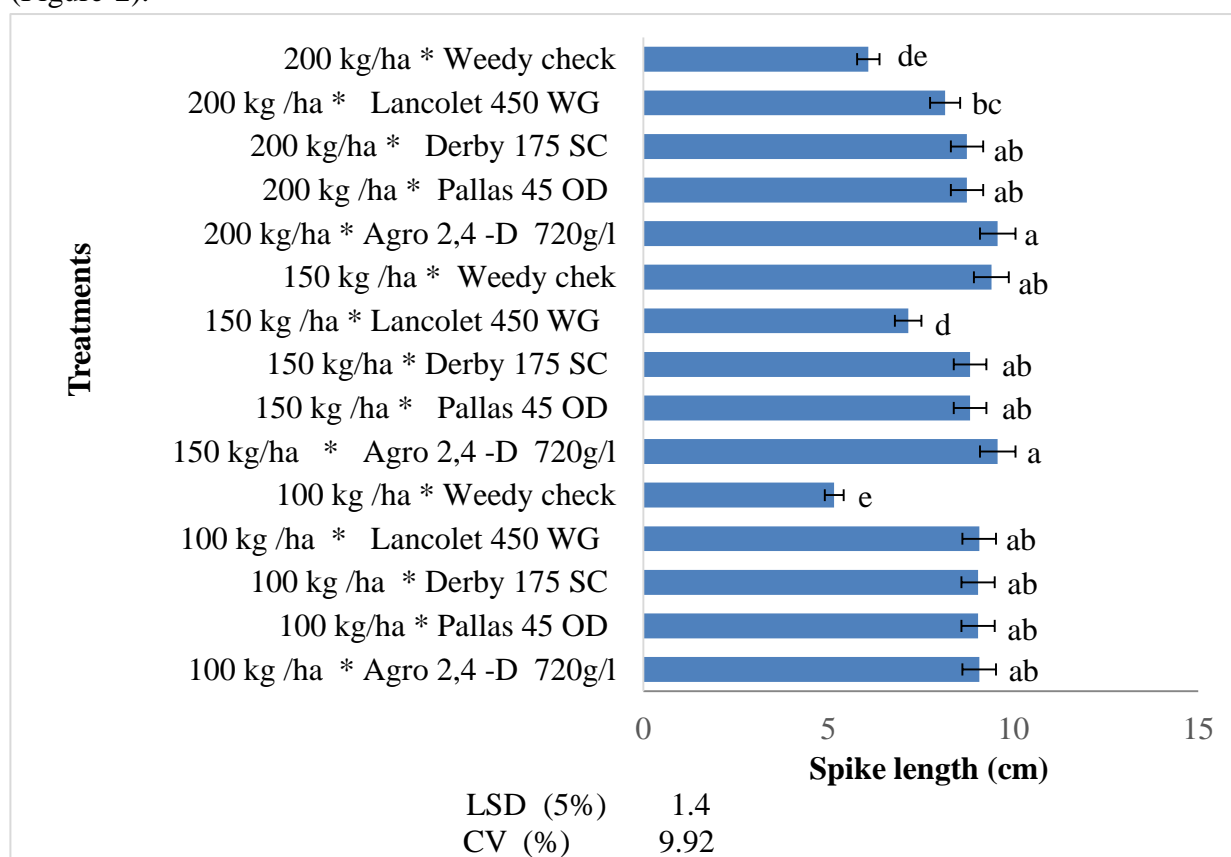
Figure 1.The effect of seed rates and herbicides on plant height (cm) in bread wheat

The application of 200 kg ha⁻¹ seed rate with 2, 4 - D 720 g/l, Pallas 45 OD and Derby 175 SC showed that statistically no significant differences. Correspondingly, the combined use of 150 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC exhibited no significant differences. The tallest plants 100 kg ha⁻¹ seed rate with weedy check indicated that the competition of weeds. The result clearly showed that plant attained its maximum height where the competition was severe for light between crop as well as weed but at lower competition, plant could not invest larger resources to attain its maximum height. Similar findings was reported from Bibi *et al* (2008) who reported that in weedy check the wheat crop invested

photosynthate in attaining the vegetative superiority by shading weeds. These findings was contradicted with the work reported by Khalil *et al.* (2009) who concluded that plant height is strongly under genetic control and but not affected by herbicides application. Plant height is a varietal character more affected by the genotype than by the environment. However, interaction of factors to some extent significantly altered plant height (Safdar *et al.*, 2011).

4.3.1.2 Spike length

The main effects of different levels of seed rates and different herbicides application had no significant effect on the spike length of wheat while the interaction of different herbicides with different levels of seeding rates had significant effect on spike length (AppendixTable-3).The highest spike length was recorded in application of Pallas 45 OD with 200 kg ha⁻¹ seed rate(9.58cm) followed by the interaction of 150 kg ha⁻¹ seeding rate with Pallas 45 OD (9.58cm) but the lowest spike lengths were recorded at weedy check (Figure-2).



Means followed by the same letter in the lower case with in column chart are not significantly different from each other at 5% level of significance

Figure 2. The effects of seed rates and herbicides on spike length (cm) in bread wheat

The interaction effects of all seed rates with all herbicides produced statistically no significant difference except for weed checks. The maximum spike length at 200 kg ha⁻¹ and 150 kg ha⁻¹ with Pallas 45 OD could be related to little availability of space for weed growth that resulted in better growing conditions for the crop to utilize resources effectively to produce longer spikes but at weedy check due to severe competition shorter spikes produced.

Similar result was reported from Tana *et al.* (2018) continuous increase in spike length which might be attributed to relief of wheat plants from weed competition leading to better growing conditions and more resources availability to the wheat plants. Asad *et al.* (2017) also stated that increase in spike length attributed to minimum crop - weed competition in treated plots and more availability of moisture that cause healthy plant growth.

4.4 Yield and yield components

4.4.1 Number of fertile tillers

The numbers fertile tillers m⁻² was significantly affected by the main effects of different herbicidal application as well as the seed rates. The interaction of herbicides with different levels of seed rates were also significant (AppendixTable-3).Maximum number of fertile tillers (133.33m⁻²) were recorded from the combined application of 150 kg ha⁻¹ seed rate with Pallas 45 OD while the minimum number of fertile tillers was recorded at weedy check plots (Table - 11).

Table 11.The effects of seed rates and herbicides on number of fertile tillers in wheat

Herbicides	Seed rates kg ha ⁻¹		
	100	150	200
Agro 2,4- D 720 g/l	128.33 ^{DE}	129.66 ^{bcDE}	130 ^{bcD}
Pallas 45 OD	131.66 ^{ABc}	133.33 ^A	132.33 ^{Ab}
Derby 175 SC	128.66 ^{cDE}	129 ^{cDE}	126.66 ^E
Lancolet 450 WG	126.66 ^E	128 ^{dE}	127 ^{dE}
Weedy check	35 ^g	85 ^F	82 ^F
LSD (1%)	3.16		
CV(%)	1.62		

Means followed by the same letter in the uppercase with in rows and the same letter in the lower case with in columns are not significantly different from each other at 1% level of significance

The combined use of all herbicides along with increased seed rates from 100kg ha⁻¹ to 200 kg ha⁻¹ statistically showed that no significant difference. Correspondingly, the application of 100 kg ha⁻¹ seed rate with 2,4 - D 720 g/l, Pallas 45 OD and Derby 175 SC caused statistically no significant difference. Furthermore, the application of 150kg ha⁻¹ seed rate with all herbicides except Pallas 45 OD showed that statistically non-significant. The combined use of 200 kg ha⁻¹ with 2, 4 - D 720 g/l and Pallas 45 OD caused statistically no significant difference and also the combined use of 200 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG resulted no significant difference. The maximum number of fertile tillers at 150 kg ha⁻¹ seed rate with Pallas 45 OD could be related with lower dry biomass of weeds, better weed control efficiency that resulted in less inter and intra specific competition of weeds with crop plants for water, nutrients and other growth factors and also due to the optimum space for wheat plants to flourish and produce fertile tillers up to their potential but the probable reason of lower number of fertile tillers in other interaction could be grasses escaped from their phytotoxicity and were competitive with wheat resulting in lower tillers. Lower number of fertile tillers in weedy check treatment can be attributed to higher weed density that resulted in competition for plant growth resources.

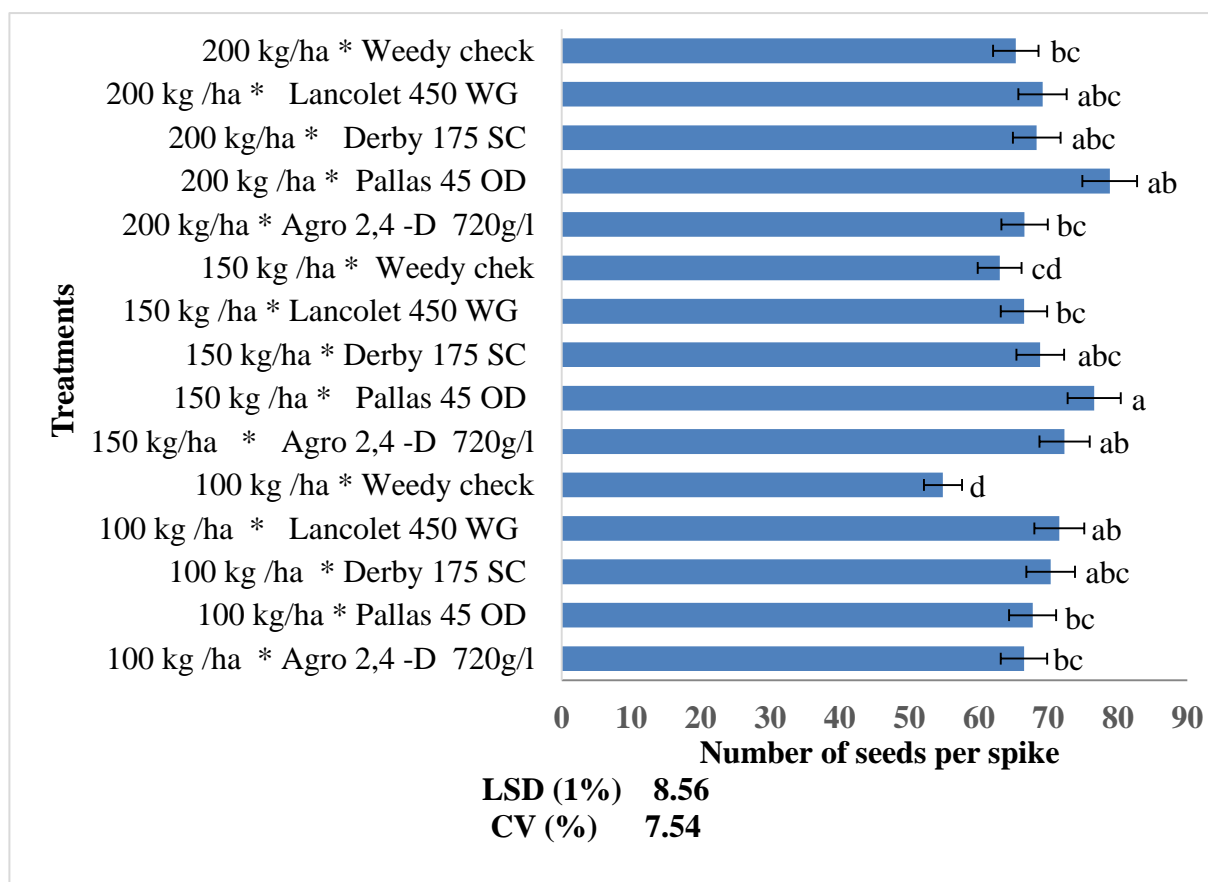
Dalga (2016) reported similar results that under low competition between weeds and crop for resources that enhanced productive tillers. Asad *et al.* (2017) also stated that increase in number of fertile productive tillers relatively better weed control which ultimately facilitated by more translocation of photosynthate towards reproductive growth due to lower weed wheat competition. Hussein *et al.* (2013) also reported that effective weed control methods could reduce dry matter of weed and increased number of wheat productive tillers.

4.4.2 Number of seeds per spike

The main effects of different herbicides application and different levels of seed rates had no significant effect on number of seeds per spike but the combined use of different levels of seed rates with different herbicides application was highly influenced the number of seeds per spike (Appendix Table-3). Maximum numbers of seeds per spike were counted at application of with 150kg ha⁻¹ seeding rate with Pallas 45 OD (76.58) which was followed by interaction effects of 200kg ha⁻¹ with Pallas 45 OD (73.08). Minimum number of grains per

spike was counted from 100 kg ha⁻¹ seed rate at the weedy check plot which was 54.83 (Figure - 3).

The application of Derby 175 SC with all seed rates showed statistically no significant difference and also application of Derby175 SC and Lancolet 450 WG showed that no significant difference results. The highest number of seeds per spike at 150 kg ha⁻¹ seed rate with Pallas 45 OD might be related to lower dry weed biomass, better weed control efficiency that contributed to the crop to have longer spikelets for producing more number of seeds. Lower number of seeds per spike can be attributed to shorter spike length in weedy check plots due to severe crop-weed competition.



Means followed by the same letter in the lower case with in column chart are not significantly different from each other at 1% level of significance

Figure 3. The effects of seed rates and herbicides on number of seeds per spike in bread wheat

Similar results have also been reported by Pandey *et al.* (2007) increase in number of grains per spike can be attributed to availability of nutrients and greater spike length of wheat. According to Ali *et al.* (2014) the number of seeds per spike increased with decreased weed competition. The poor grain filling due to presence of weeds was reported to be due to reduced tillering, ear formation, and stem weight and height reduction in wheat (Fazal *et al.*, 2012).

4.4.3 Thousand grain weight

The application of different levels of seed rates did not impose significant effect on thousand grain weight but the use of different herbicides and the combined use of seed rates with herbicides had a significant effect on thousand grain weight (Appendix Table - 4). Maximum thousand grain weight was recorded at application of Pallas 45 OD with 150 kg ha⁻¹ seed rate (44.36 gm) followed by combined use of Pallas 45 OD with 200 kg ha⁻¹ seed rate (42.6 gm) while minimum number of thousand grain weight was recorded at weedy check (Table - 12).

Table 12. The effects of seed rates and herbicides on thousand grain weight (gm) in bread wheat

Herbicides	Seed rates kg ha ⁻¹		
	100	150	200
Agro2,4 -D 720 g/l	39.86 ^{BC}	40.66 ^{BC}	41.2 ^{BC}
Pallas 45 OD	41.2 ^{bc}	44.36 ^a	42.6 ^{ab}
Derby 175 SC	42 ^{abC}	41.06 ^{bc}	39.06 ^C
Lancolet 450 WG	41.73 ^{aBc}	41.6 ^{aBc}	39.86 ^B
Weedy check	31.86 ^e	36 ^d	28.40 ^f
LSD (5%)	3.03		
CV (%)	4.61		

Means followed by the same letter in the uppercase with in rows and the same letter with in columns in the lower case are not significantly different from each other at 5% level of significance

The ANOVA result showed that the interaction of 2, 4-D 720 g/l with all seed rates caused statistically no significant difference and also application of Lancolet 450 WG with 100 kg ha⁻¹ and 150 kg ha⁻¹ seed rates showed no significant differences. The highest thousand grain weight at 150 kg ha⁻¹ seed rate with Pallas 45 OD could be related to lower dry weed biomass, better weed control efficiency, minimum intra and inter-specific competition that enable the crop to utilize resources efficiently to produce well vigor seeds but at weedy

check treatments lowest number of thousand grain weight was due to higher competition of plant growth resources that resulted in less vigor seeds.

Similar results from Pandey *et al.* (2007) reported that lower thousand grain weight in weedy check and availability of nutrients and better plant growth might be the reason for heavier grains in high fertilizer levels.

4.4.4 Grain yield

The grain yield was significantly affected by the application of different levels of seed rates and herbicides application. The interaction effects of different seed rates with different herbicides were also highly significant (AppendixTable-4).Maximum grain yield was obtained at combination of Pallas 45 OD with 150 kg ha⁻¹ seed rate (4516.42 kg ha⁻¹) followed by interaction of Pallas 45 OD with 200 kg ha⁻¹ seed rate (4346.58 kg ha⁻¹) while minimum grain yield (1025 kg ha⁻¹) was obtained from the combination of 100 kg ha⁻¹ seed rate with weedy check (Table - 13).

Table 13.The effects of seed rates and herbicides on grain yield (kg ha⁻¹) in bread wheat

Herbicides	Seed rates kg ha ⁻¹		
	100	150	200
Agro2,4 –D 720 g/l	3745.17 ^G	4033.67 ^d	3858.17 ^{ef}
Pallas 45 OD	3813.17 ^{fG}	4516.42 ^a	4346.58 ^b
Derby 175 SC	3838.83 ^{efG}	4176.5 ^C	4053.83 ^D
Lancolet 450 WG	3928.25 ^e	4210.08 ^C	4034.75 ^D
Weedy check	1025 ⁱ	1243.33 ^h	1348.33 ^h
LSD(1%)	105.37		
CV (%)	1.81		

Means followed by the same letters in the upper case with in columns are not significantly different from each other at 1% level of significance

The application of Derby 175 SC and Lancolet 450 WG with 150 kg ha⁻¹ seed rate showed that statistically no significant difference and also interaction of 200 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG caused statistically no significant difference. The increased seed rates from 100 kg ha⁻¹ to 150 kg ha⁻¹ with interaction of all herbicides showed significant increase in grain yield. The highest number of grain yield at 150 kg ha⁻¹ seed rate with pallas 45 OD could be related to less weed competition with crop for plant growth

factors and optimum space for wheat plants to flourish and produce fertile tillers up to their potential, more number of seeds per spike, thousand grain weight and higher number of total biomass production. The herbicide also had the ability of controlling various weed species and persistent. However, the lower grain yield at weedy check treatments was due to the severe inter and intra specific competition that resulted in lower yield and yield components.

The result of this study was similar with Nadeem *et al.* (2006) which stated that different herbicidal treatments had a significant effect on grain yield of wheat. The greatest reduction of yield was occurred when no herbicide was applied. Increased in yield in herbicides treated plots were due to the efficient weed control and thus the crop utilized all the available resources. These results are in confirmity with the work of Tunio *et al.* (2004) who reported that herbicidal treatments significantly increased grain yield in wheat. Ali *et al.* (2014) also stated that maximum grain yield was at weed free due to less weed population, better nutrient and water use efficiency but minimum at weedy check.

4.4.5 Biological yield

The main effects of seed rates and herbicides application highly influenced biological yield. The biological yield was also highly influenced by the interaction effects of seed rates with herbicides (AppendixTable - 4).The maximum biological yield was obtained from the combination of Pallas 45 OD with 150 kg ha⁻¹ seed rate (13100 kg ha⁻¹) followed by the interaction of Pallas 45 OD with 200 kg ha⁻¹seed rate (12100 kg ha⁻¹). However, minimum biological yield (4566.7 kg ha⁻¹) was obtained from interaction of 100 kg ha⁻¹ seed rate with weedy check (Table - 14).

Table 14. The effects of seed rates and herbicides on biological yield (kg ha⁻¹) in bread wheat

Herbicides	Seed rates kg ha ⁻¹		
	100	150	200
Agro 2,4 - D 720 g/l	7483.3 ^H	9580 ^{ef}	7900 ^{gh}
Pallas 45 OD	7700 ^{gH}	13100 ^a	12100 ^{ab}
Derby 175 SC	7900 ^{gH}	11466.7 ^{BCd}	10433.3 ^{DE}
Lancolet 450 WG	8693.3 ^{fg}	11583.3 ^{BC}	10566.7 ^{Cde}
Weedy check	4566.7 ^j	5450 ^{ij}	5750 ⁱ
LSD (1%)	1084.4		
CV (%)	7.26		

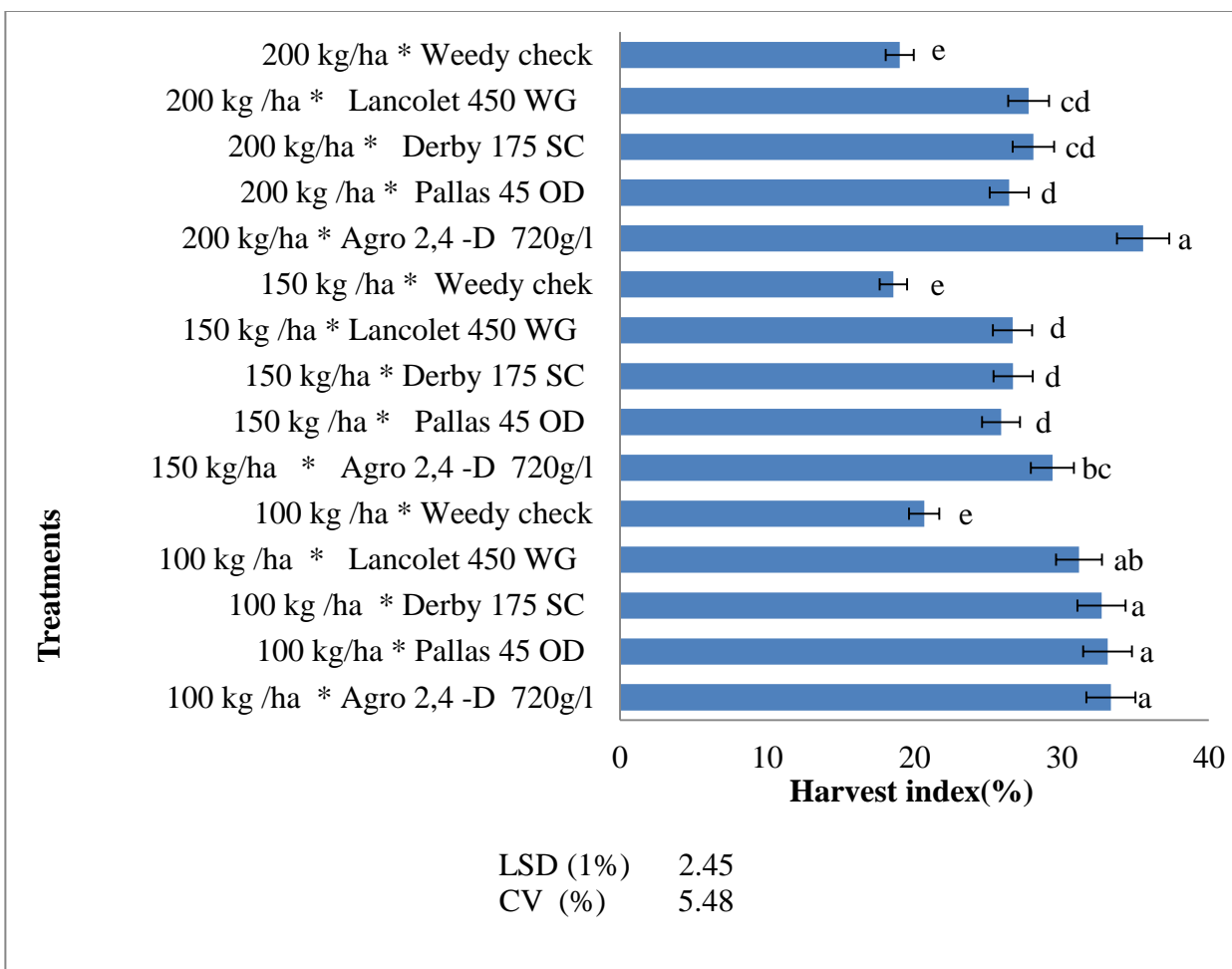
Means followed by the same letter in the upper case with in columns and lower case with in rows are not significantly different from each other at 1% level of significance

The combined use of 100 kg ha⁻¹ seed rate with Pallas 45 OD and Derby 175 SC exhibited statistically no significant differences. Similarly, the interaction of 150 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG revealed that statistically no significant difference. Moreover, the interaction of 200 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG revealed that statistically no significant difference. The general results showed that increased in biological yield as seed rates increased from 100 to 150 kg ha⁻¹ seed rates by all herbicides application. The higher number of biological yield at 150 kg ha⁻¹ seed rate with pallas 45 OD related to less weed competition with crop plants for water, nutrients and other growth factors and due to the optimum space for wheat plants to flourish and produce fertile tillers up to their potential, more number of seeds per spike and thousand grain weight that contributed to biological yield. However, the lowest biological yield at weed check signified severe competition of weeds resulted in fewer number of plants in plots.

Therefore, it can be concluded that higher seeding rate should be used in combination with broad spectrum herbicide that limited weed growth in the field and increase biological yield. Similar results were reported from Ali and Awan (2004) who stated that decreasing the biological yield in wheat might be due to weed competition as a consequence of depletion of nutrient supply and water by weeds, which resulted in reduced growth, seed and straw yields of crop plants. However, it is suggested that high seed rates were found to increase yield in well watered conditions, whereas the reverse was true with low soil moisture (Marwat *et al.*, 2011).weed control methods increased biological yield of wheat reducing the weed infestation (Zahoor *et al.*,2012).

4.4.6 Harvest index

The main effects of different seed rates and different herbicides and their interaction showed highly significant effect on harvest index (Appendix Table-4).The highest harvest index was observed at interaction of 200 kg ha⁻¹ seed rate with 2,4-D 720g/l (35.53%) closely followed by interaction of 100 kg ha⁻¹ seed rate with 2,4 -D 720g/l (33.34%). The minimum harvest index (18.56%) was obtained from combination of 150 kg ha⁻¹ with weedy check (Figure - 4).



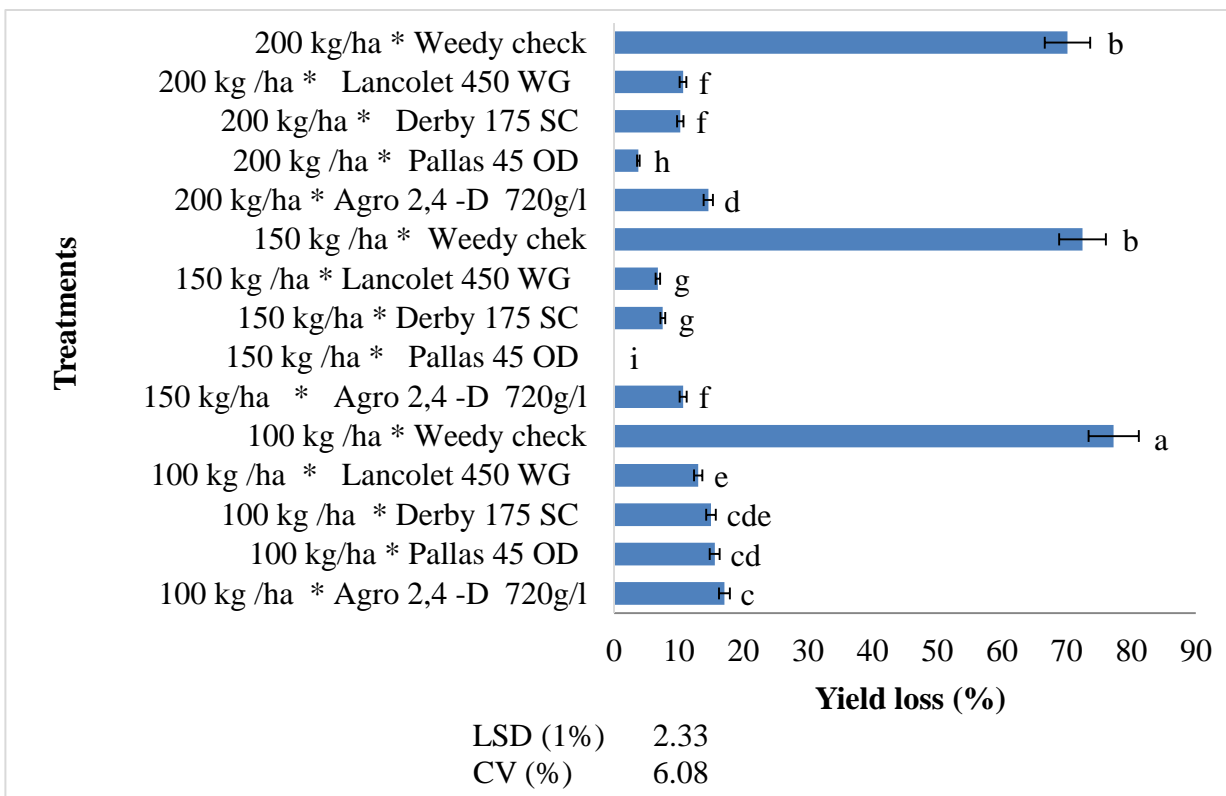
Means followed by the same letter in the lower case with in column chart are not significantly different from each other at 1% level of significance

Figure 4. The effects of seed rates and herbicides on harvest index (%) in bread wheat

The application of 100 kg ha⁻¹ seed rate with 2,4 -D 720 g/l , Pallas 45 OD and Derby 175 SC showed that no significant differences and also the combined effects of Pallas 45 OD with 150 and 200 kg ha⁻¹ exhibited statistically no significant differences. The maximum number of harvest index at higher seed rate of 200 kg ha⁻¹ in combination with 2, 4-D might be related to higher in total biomass production. The result also clearly indicated that harvest index was lower at higher total biomass production. Similar findings were reported from Ali *et al.*(2014) and Amare *et al.*(2014) concluded that harvest index increased with decreased in weed competition. Sujoy *et al.* (2006) was also reported that significant variation in harvest index of wheat due to weed control treatments.

4.4.7 Yield loss

The main effects of seed rates, herbicides and their combined effects were highly significant at on yield loss of bread wheat(Appendix Table - 3).The combined effects of using 150 kg ha⁻¹ seed rate with Pallas 45 OD gave no significant yield loss as compared to other interactions and also minimum yield loss was obtained from the interaction effects of 200 kg ha⁻¹ with Pallas 45 OD (3.75%).The combined effects of 100 kg ha⁻¹,150kg ha⁻¹ and 200 kg ha⁻¹ seed rates with weedy check plots gave higher yield loss which was 77.3%,72.46% and 70.14% respectively(Figure - 5).



Means followed by the same letter in the lower case with in column chart are not significantly different from each other at 1% level of significance

Figure 5. The effects of seed rates and herbicides on yield loss (%) in bread wheat

The application of 100 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG resulted no significant differences. Similarly, application of 200 kg ha⁻¹ seed rate with Derby 175 SC and Lancolet 450 WG revealed no significant differences. The lowest yield loss at 150 kg ha⁻¹ seed rate with pallas 45 OD could be related to higher weed control efficiency, more number

of yield components and better crop growing conditions to produce higher yield. In contrast, higher weed biomass resulted in greatest yield reduction due to competition for growth resources and fewer number of wheat in the plots.

The highest yield loss obtained from weedy check plots as a result of higher weed density and competition. The finding was in conformity with the work of Amare *et al.*(2014) reported that highest yield loss was at weedy check and under poor weed control. On the other hand, Karlen *et al.* (2002) reported a yield reduction as high as 80% in wheat due to weed competition throughout the crop growing season.

4.5 Correlation analysis

The simple correlation analysis among most of the traits were statistically highly significant (Table-15). Dry weed biomass was positively ($P < 0.01$) correlated with yield loss but negatively related with weed control efficiency, number of tillers, number of seeds per spike, thousand grain weight, grain yield and biological yield. The correlation result also indicated that weed control efficiency was positively correlated with number of tillers, seeds per spike, thousand grain weight, grain yield and biological yield. The yield loss was negatively correlated with yield and yield components except weed dry biomass. The number of tillers had positive d with number of seeds per spike, thousand grain weight, grain yield and biological yield. The number of seeds per spike had positive relationship with thousand grain weight, grain yield and biological yield.

Table 15. The correlation analysis of weed parameters, yield and yield components and yield loss in bread wheat at Holeta 2018/19 main cropping season

Traits	DBL	DGW	WCE	TILL	SPS	TGW	YLD	BY	YL
DBL	1								
DGW	0.71**	1							
WCE	-0.98**	-0.70**	1						
TILL	-0.96**	-0.67**	0.92**	1					
SPS	-0.60**	-0.53*	0.58**	0.63**	1				
TGW	-0.80**	-0.55*	0.85**	0.81**	0.53*	1			
YLD	-0.98**	-0.74**	0.99**	0.93**	0.58**	0.85*	1		
BY	-0.76**	-0.78**	0.76**	0.72**	0.58*	0.70*	0.83*	1	
YL	0.98**	0.74**	-0.99**	-0.93**	-0.58**	-0.85**	-1**	-0.83**	1

** indicates significant at 1%, *=significant at 5%, NS=non-significant, DBL=dry biomass of broad leaf weeds, DGW=dry biomass of grass weeds, WCE=weed control efficiency, TILL=number of tillers, SPS=seeds per spike, TGW=thousand grain weight, GY=grain yield, BY=biological yield and YL=yield loss

4.6 Economic analysis

Fixed costs were not considered in this study and the highest total variable cost Ethiopian birr 9784 ha⁻¹ was recorded from the interaction of 200 kg ha⁻¹ seed rate with Pallas 45 OD 0.5L

ha⁻¹ whereas the highest net return of Ethiopian birr 54887.70 ha⁻¹ was gained from 150 kg ha⁻¹ seed rate with Pallas 45 OD 0.5L ha⁻¹ which was followed by 200 kg ha⁻¹ seed rate with Pallas 45 OD 0.5L ha⁻¹ (48894.80 birr ha⁻¹). The highest benefit cost ratio (7.24) was obtained from interaction of lancolet 450 WG with 100 kg ha⁻¹ seed rate while the minimum was at weedy check plots. The highest marginal rate of return (80.89) was obtained from the interaction effects of 150 kg ha⁻¹ seed rate with 2, 4-D (Table-16).

Table 16. The economic analysis of seed rates and herbicides types on adjusted grain yield and gross benefit on bread wheat in 2018/19 main cropping season

Treatments	Average Yield (kg ha ⁻¹)	Adjusted yield (kg ha ⁻¹)	GB (Birr ha ⁻¹)	TVC (Birr ha ⁻¹)	NB (Birrha ⁻¹)	MRR	B:C
100kg * 2,4-D 720g/l	3745.17	3370.65	50559.75	7084	43475.75	78.83	7.14
100 kg * Pallas 45 OD	3813.17	3431.85	51477.75	8384	43093.75	20.38	6.14
100 kg * Derby 175 SC	3838.83	3454.95	51824.25	7524	44300.25	42.31	6.89
100kg*Lancolet450WG	3928.25	3535.43	53031.45	7284	45474.45	57.97	7.24
100kg * weedy check	1025.00	922.50	13837.50	6624	7213.50	0.00	2.09
150 kg * 2,4-D 720g/l	4033.67	3630.30	54454.50	7784	46670.50	80.89	7.00
150 kg * Pallas 45 OD	4516.42	4064.78	60971.70	9084	54887.70	25.81	7.00
150 kg * Derby175SC	4176.50	3758.85	56382.75	8224	48158.75	43.00	6.90
150 kg * Lancolet450WG	4210.08	3789.07	56836.05	7984	48852.05	59.68	7.10
150 kg * weedy check	1243.33	1119.00	16785.00	7324	9461.00	0.00	2.30
200 kg * 2,4-D 720g/l	3858.17	3472.35	52085.25	8484	43601.25	72.65	5.20
200 kg * Pallas 45 OD	4346.58	3911.92	58678.80	9784	48894.80	22.00	6.00
200kg * Derby 175SC	4053.83	3648.45	54726.75	8924	45802.75	39.58	6.13
200kg*Lancolet450 WG	4034.75	3631.28	54469.20	8684	45785.20	53.95	6.27
200kg * weedy check	1348.33	1213.50	18202.50	8024	10178.50	0.00	2.27

The cost of variable inputs were described as: cost of pallas 45 OD =3400 ETB /L, cost of Agro 2,4-D 720 g/l =400 ETB/L, cost of Derby 175 SC =8400ETB/L, cost of lancolet 450 WG= 18,181.80 ETB/kg ,Spraying cost= 60 ETB/ ha, cost of Urea= 1280 ETB/100 kg and cost of NPS=1440 ETB/100kg.The field labor cost for sowing, harvesting, threshing and transportation 50 labors/ha each at 38 ETB per person net income was the product of market price and adjusted grain yield.

The higher number of marginal rate of return was obtained from the application of 2, 4-D at all seed rates combinations as compared to other interactions. The relative net returns increased with increasing seed rates with application herbicides that was probably due to better control of weeds that consequently resulted in increased grain yield. Furthermore, interaction of higher seed rates with herbicides showed that better relative returns over lower seed rate with herbicides application as the result of better weed management. The similar result was reported from Babu *et al.* (2017) and Kalid *et al.*, (2014) suggested that herbicides combinations with higher seed rates effectively controlled weed infestation in bread wheat and gave higher yield that related directly with high relative net return. All interaction of seed rates and herbicides application gave higher net benefit over weedy checks.

5. SUMMARY AND CONCLUSION

Bread wheat is one of major food grains that contain different nutrient and cultivated from small to large scale farmers in Ethiopia. Weed management practices such as optimum seed rates and promising herbicides are among the important methods for the management of weeds to improve wheat production and productivity. The integrated weed management practices such as optimum seed rates and herbicides nowadays advantageous than using single weed management practices for good weed control as well as obtaining maximum yield. Therefore, this study was designed to investigate the effects of seed rates and post emergence herbicides application on weed growth and productivity of wheat.

All of the traits studied were significantly affected by the interaction of different levels of seed rates with herbicides application. The minimum number of weed density, dry biomass of weeds and weed control efficiency were recorded at interaction of 150 kg ha⁻¹ seed rate with Pallas 45 OD but no weed control at weedy check while the maximum numbers of weed density and dry biomass were obtained from weedy checks. Longer duration of days to heading was recorded at weedy checks but there is no much significant variation due to other interactions. The maximum number of productive tillers, seeds per spike, thousand grain weight, grain yield and biological yield were obtained from the combined effects of 150 kg ha⁻¹ seed rate with Pallas 45 OD but the maximum plant height was recorded from application of 100 kg ha⁻¹ seed rate at weedy check. The combined use of 200 kg ha⁻¹ seed rate with Pallas 45 OD resulted in maximum spike length. The biological yield and grain yield increased significantly with the increase of seed rates. The maximum harvest index was observed at interaction of lower seed rate with 2, 4-D. Dry weed biomass was positively related with yield loss but negatively related with other traits studied. The grain yield was positively correlated with yield components but has a negative relationship with that of dry biomass of weeds.

The combined effects of using 150kg ha⁻¹ seed rate with Pallas 45 OD gave non-significant yield loss as compared to other interactions and also minimum yield loss was calculated from the interaction effects of 200kg ha⁻¹ with Pallas 45 while highest yield loss was obtained at weedy check plots. The maximum variable cost was obtained from using of 200 kg ha⁻¹ seed

rate with Pallas 45OD due expensive costs of inputs. The maximum net benefit was gained from the combined use higher seed rates of 150 kg ha⁻¹ with Pallas 45 OD closely followed by 200 kg ha⁻¹ with Pallas 45 OD than using lower seed rates. The maximum benefit cost ratio was obtained from the interaction effects of 100 kg ha⁻¹ seed rate with lancolet 450 WG.

The use of higher seed rates was effective as compared to lower seed rate 100 kg ha⁻¹ for weed control and obtaining maximum yield. The herbicides having the ability of controlling various weed species gave better yield advantages as well as for good weed management over narrow spectrum herbicides. Pallas 45 OD is recommended for controlling various weed species in wheat field at small scale and commercial farms. The combined use of seed rate of 150 kg ha⁻¹ with Pallas 45 OD effectively managed weeds, economical and gave maximum yield. However, more yield advantages obtained from using interaction of 150 kg ha⁻¹ seed rate with application of broad spectrum herbicides Pallas 45 OD. Since the experiment was conducted for one season and location, it should be repeated over seasons or multiple locations for best recommendation.

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7. APPENDIXES

Appendix Table 1. Mean squares of analysis of variance showing individual weed densities after application as affected by seed rates and herbicides on wheat at Holeta during 2018/19 cropping season

Source of variation	DF	Mean squares											
		<i>Polygonum nepaense</i> L.	<i>Raphanus raphanistrum</i> L.	<i>Plantago lanceolata</i> L.	<i>Cyanotis barbata</i> D. Don.	<i>Corrigiola capensis</i> Wild	<i>Spergula arvensis</i> L.	<i>Galinsoga pulviflora</i> Cav.	<i>Arthraxon prinodes</i> L.	<i>Guizotia scabra</i> (Viz)	<i>Setaria pumila</i> L.	<i>Phalaris paradoxa</i> L.	<i>Oxalis corniculata</i> HBK.
REP	2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SR	2	0.9**	0.8*	0.1*	2.07**	0.2**	0.2**	0.2**	0.4**	0.2**	1.4**	1.3**	0.2**
WC	4	6.1**	6.2**	0.3*	1.37**	1.1**	1.2**	1.4**	0.3**	1.6**	6.4**	6.0**	0.2**
SR*WC	8	0.1*	0.1*	0.1*	0.16*	0.3**	0.4**	0.6**	0.7**	0.8**	0.2*	0.1*	0.4**
Error	28	0.3	0.28	0.3	0.26	0.1	0.11	0.12	0.2	0.1	0.3	0.3	0.1
CV (%)		8.97	8.34	9.91	7.28	2.9	3.14	3.69	6.1	3.92	11.96	12.86	3.21

DF = Degrees of Freedom, *SR* = Seed rates, *WC* = Herbicides, *NS* = non-significant, * = significantly different at 5%, and ** = significantly different at 1% level of significance, *CV* = Coefficient of Variation

Appendix Table 2. Mean squares of analysis of variance for weed parameters as affected by seed rates and herbicides on wheat at Holeta during 2018/19 cropping season

Source	DF	Mean square				
		WD (m ⁻²) at 25 DAP	WD (M ⁻²) at 45 DAP	DBLB (kg ha ⁻¹) at harvest	DGWB (kg ha ⁻¹) at harvest	WCE (%) at harvest
Rep	2	NS	NS	NS	NS	NS
SR	2	0.76 **	0.76**	10023.8**	361.67 **	29.34 *
WC	4	1.67 ^{NS}	1.67**	22021**	607.86**	10097.9*
SR * WC	8	0.05 **	0.05**	1664.86**	43.61 ^{NS}	4.31**
Error	28	0.07	0.02	147.46	37.38	7.91
CV (%)		5.25	4.72	8.97	12.55	4.68

Where, WD = Weed Density, DBLB=Dry Broad Leaf Weeds Biomass, DGWB = Dry Grass Weeds Biomass, WCE (%) = Weed Control Efficiency, DAP = Days after planting, DF = Degrees of Freedom, SR= Seed rates, WC = Herbicides, NS= non-significant, * = significantly different at 5%, and ** = significantly different at 1% level of significance, CV = Coefficient of Variation

Appendix Table 3. Mean squares of analysis of variance for Crop phenology, plant growth and some yield components parameters as affected by seed rates and herbicides on wheat at Holeta during 2018/19 cropping season

Source	DF	Mean square				
		DH	PH (cm)	NPT(m ⁻²)	SL (cm)	NSP
REP	2	NS	NS	NS	NS	NS
SR	2	23.88 ^{NS}	2.29 ^{NS}	517**	0.73 ^{NS}	41.89 ^{NS}
WC	4	108.88**	67.21 ^{NS}	6992.48**	15.98 ^{NS}	159.69 ^{NS}
SR * WC	8	11.38*	6.73**	447.01**	0.85*	41.22**
Error	28	3.23	6.24	3.25	0.70	27.99
CV (%)		4.99	2.66	1.62	9.92	7.54

Where, DH=Days to Heading, PH = Plant Height, NPT= Number of Productive Tillers, SL = Spike Length, NSP = Number of Seeds per Spike, DF = Degrees of Freedom, SR= Seed rates, WC = Herbicides, ns= non-significant, * = significantly different at 5%, and ** = significantly different at 1% level of significance, CV=coefficient of Variation, NS=Non Significant

Appendix Table 4. Mean squares of analysis of variance showing yield and yield components as affected by seed rates and herbicides on wheat at Holeta during 2018/19 cropping season

Source	DF	Mean square				
		TGW(gm)	BY(kg ha ⁻¹)	GY (kg ha ⁻¹)	HI (%)	YL(%)
REP	2	NS	NS	NS	NS	NS
SR	2	23.80**	34926562**	530450.45**	90.87**	260.03**
WC	4	158.33**	46820281**	14662183**	198.76**	7188.16**
SR * WC	8	9.63*	2774817**	41735.21**	5.31*	20.46**
Error	28	3.50	449285.1	3891.88	2.26	1.90
CV (%)		4.61	7.26	1.81	1.62	6.08

Where, TGW = Thousand Grain Weight, BY = Biological Yield, GY = Grain Yield, HI = Harvest Index, DF = Degrees of Freedom, SR = Seed rates, WC = Herbicides, NS = non-significant, * = significantly different at 5%, and ** = significantly different at 1% level of significance, CV = Coefficient of Variation

Appendix Table 5.The images of weed species in the experimental field in wheat at Holeta



Fig.1 *Raphanus raphanistrum* L.



Fig.2 *Polygonum nepalense* L.



Fig.3 *Galinsoga pulviflora* Cav.



Fig.4 *Plantago lanceolata* L.



Fig.5 *Spergula arvensis* L.



Fig.6 *Corrigiola capensis* Wild.



Fig.7 *Oxalis corniculata* HBK



Fig.8 *Arthraxon prinodes* L.



Fig.9 *Phalaris paradoxa* L.



Fig.10 *Guizotia scabra* (VIS) Chiov



Fig.11 *Staria pumila* L.



Fig.12 *Cyanotis barbata* D.Don