Integrated Weed Management in Wheat under Subtropical Rain-Fed Conditions

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Abstract: A field experiment was carried out from July, 2013 to May, 2014 at University Research Farm Chakwal Road, of Pir Mehr Ali Shah-Arid Agriculture University, Rawalpindi to evaluate the integrated weed control management strategies followed by summer green manure practices on weeds and grain yield of wheat under rain-fed conditions. The experiment was laid out in a 2-factor factorial Randomized Complete Block Design (RCBD) in strip plot arrangement with three replications of each treatment. The sorghum and sesbania crops were sown in the first week of July, 2013 and incorporated into soil as green manure at the end of August, 2013 after attaining sufficient biomass. The wheat variety “Chakwal-50” was sown with a tractor drawn rabi drill in the last week of October, 2013 with a seeding rate of 125kg ha^{-1}. The herbicides used were buctril super @ 750ml ha^{-1} and isoproturon @ 1.00kg a.i. ha^{-1}. The weeds found in the wheat crop were *Fumaria indica* L., *Convolvulus arvensis* L., *Chenonpodium album* L., *Asphodelus tenuifolius* L. The incorporation of sorghum green manuring resulted in good control to suppress the weed population and biomass. The buctril super @ 750ml ha^{-1} along with tharphali significantly reduced the weed density (18.8 m^{-2}), weed biomass (12.7g m^{-2}) and increased weed control efficiency (71.1%) followed by isoproturon applied @ 1.00kg a.i. ha^{-1}. The highest grains yield of 3208.5kg ha^{-1} was recorded in the plots where weeds were controlled with buctril super @ 750ml ha^{-1} followed by tharphali where sorghum green manure was incorporated in summer followed by the isoproturon application @ 1.00kg a.i. ha^{-1}(3016.1kg ha^{-1}) in combination with tharphali in the same green manuring crop.

Keywords: Integrated weed management, weeds, green manuring, herbicides, wheat (*Triticum asetivum* L.).

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereals and is produced all over the world. It is the prominent staple food and the leading grain crop of Pakistan and sufficiently feeds the masses in the country. It is grown on areas of 9.06 million ha with total production of about 25 million tons. Wheat average yield is approximately 2.83 t ha^{-1}. However, in rain-fed conditions, the total cultivated area of wheat crop is around 1.24 million ha with the crop yield of 1.94 million tons and the average yield of almost 1.53 t ha^{-1}. In spite of the combined struggles of researchers and farmers, these yields are still failing to achieve the potential yield of wheat crops (i.e.6 t ha^{-1}).

Weed infestation is a serious problem affecting the yield of wheat. The statistical range of wheat yield reduction in Pakistan caused by weeds is about 20-30% [1]. Weeds are the foremost barrier in the production of wheat as they decrease the crop productivity by competing for soil moisture, nutrients, light, and CO_2. They exude allelopathic chemicals in the soil; provide environments for disease causing agents along with the allocation of substitute host for several insects; and increase the cost of harvesting [2]. Weeds are responsible for declining crop yield, not only through competing for essential limiting factors of plant growth and development, but also through the release of certain allelochemicals from the root system and other parts of plants into the root zone of desired crop plants.

Incorporation of green manure residues into the soil has a significant influence on the weed’s life span by reducing weed seed germination, and restricting growth and development of individual weed species [3]. Herbicides successfully control weeds and improve the grain yield of crops [4-6]. In cropping system it is very effective method of weed control as it minimizes the crop productivity losses due to weed invasion and reduces the subsequent infestation of weeds at low and persistent levels.

Integrated weed management (IWM) is a policymaking process based on the basic principles of science that bring together the information of climate, weed life span i.e. seeds, newly emerged plant, vegetative growth stages, flowering and seed set, and their relationship to the environment and all accessible approaches for weed management by the most cost-effective and environmentally sustainable methods [7].

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IWM is a multiple-approached weed control strategy to minimize the weed population. This concept includes various weed control methods such as herbicides, conservation and conventional tillage systems, crop rotation, crop topping, incorporation of green manure crops into the soil, seed capture at harvest, flaming and grazing. IWM would reduce herbicide resistance in weed species on long-term coverage [8]. IWM may be responsible for a more workable system of weed control [9]. Green manuring can retard weed germination in soils through effects on the radiation and chemical composition of the seed. Sarrantonio and Gallandt [10] reported that when fresh residue is incorporated into soil, the decomposition process can release phytotoxins that inhibit germination and early growth of weeds. The incorporation of green manures significantly affected the weed life cycle [11]. The allelopathic green manuring crops released allelochemicals of different chemistry that suppressed the weeds in subsequent crops. Along with the allelopathic effect the green manure, crop residues also retard weed seed emergence and growth by other mechanisms.

Keeping in view the importance of wheat and weed associated problems this study ought to be considered an essential component of integrated weed management. The objectives of the study were; to evaluate the impact of integrated weed control practices for suppressing weeds in wheat crop and to improve wheat grain yield within green manuring option under rainfed conditions.

2. MATERIAL AND METHODS

A field experiment was conducted to evaluate the multi-approached weed control methods in wheat with the objective to investigate the effect of different green manuring and application of herbicides on weeds in a wheat crop under rainfed conditions. The experiment was carried out at the University Research Farm, Chakwal Road (33° 07′ 00.2″ N; 73° 00′ 53″ E), of Pir Mehr Ali Shah-Arid Agriculture University, Rawalpindi during July, 2013 - May, 2014. The experiment was laid out in 2 factor factorial Randomized Complete Block Design (RCBD) in strip plot arrangement with three replications of each treatment. The plot size was 2×3 m. The sorghum green manuring crop was sown at 75kg ha^{-1} and the sesbania was sown at 45kg ha^{-1} in the first week of July, 2013 and incorporated into the soil with the help of disc harrow and rotavator in late August, 2013. The wheat variety Chakwal-50 was sown by using the recommended seed rate of 125kg ha^{-1} with the help of Rabi drill in the last week of October, 2013. The fertilizers NPK were applied at the time of sowing at 90-60-60kg ha^{-1} as a basal dose, respectively. All the cultural practices were followed according to the recommendations. Treatments were: Green manuring: GM_1= Without Green Manuring, GM_2= Sorghum (*Sorghum bicolor* L.), GM_3= Sesbania (*Sesbania rostrata* L.), While winter weed control methods: WCM_1: Weedy Check (Control), WCM_2: Hand Hoeing, WCM_3: Buctril Super @ 750ml ha^{-1}, WCM_4: Isoproturon 50WP @ 1.00kg a.i. ha^{-1}, WCM_5: Tharphali, WCM_6: Tharphali + Buctril Super @ 750ml ha^{-1}, WCM_7: Tharphali + Isoproturon 50WP @ 1.00kg a.i. ha^{-1}.

2.1. Plant Biometrical Measurement

Weed population was recorded using a quadrate of one meter square, taking two samples from each plot before and after application of treatments and at wheat harvest; the average was determined. Weed biomass was taken at harvesting time and was placed in an oven at 65^{o}C for 48 hours and dry matter weight was recorded. Fresh biomass of weed was taken out from treated and untreated plot and was dried at 65^{o}C using an oven. Dry matter and weed control efficiency was calculated using the following formula.

$$WCE\ (\%) = \frac{DMWut - DMWt}{DMWut} \times 100$$

Where:

DMWut= Dry matter of weed from un-treated plots

DMWt= Dry matter of weed from treated plots

The spike length was recorded in centimeters starting from the base to the end of the spike, but not including awns, of 10 randomly selected spikes and the average was calculated. The spikelets per spike were recorded by taking a sample of ten spikes. The average value was calculated. The grains per spike were determined by counting the grains of ten randomly selected spikes and their average value was calculated for analysis. For measuring the 1000-grains weight, three samples from the produce of each experimental plot were recorded. The samples were weighed in grams and the average was calculated. At maturity each plot was harvested, weighed for biological yield, and after threshing total yield per plot was recorded and calculated. The statistical analysis of mean data was done by using the software STATISTIX 8.1. The meteorological data of experimental site are given in Table **1**. The least significant difference (LSD)

Table 1: Meteorological Data (Temperature and Average Rainfall) of Chakwal During the Growth Period of Wheat

Months	Temperature (°C)			Rainfall (mm)
	Maximum	Minimum	Average	
October, 13	32.29	18.35	25.32	24.6
November, 13	23.49	7.65	15.57	14.3
December, 13	20.40	2.75	11.58	4.3
January, 14	23.42	6.45	14.94	0.0
February, 14	18.22	6.35	12.29	37.4
March, 14	19.70	9.16	14.43	94.1
April, 14	25.48	16.10	20.79	66.0
May, 14	26.11	23.13	24.62	67.5
Total Rainfall				308.2

test at 0.05 probability levels to compared the difference among treatments means.

3. RESULTS AND DISCUSSIONS

3.1. Effect of Various Treatments on Weed Growth

3.1.1. Weed Density (m^{-2})

The existing weed species of the experimental area were *Fumaria indica* L., *Convolvulus arvensis* L., *Chenonpodium album* L., *Asphodelus tenuifolius* L. Statistical analysis of data, as presented in Table **2**, illustrated that there was a significant effect of sorghum and sesbania green manures and different weed control methods on weed density in wheat. The green manuring effect was statistically significant to reduce the weed density when compared with plots where no green manuring was practiced.

The minimum weed density of 39.0m^{-2} was recorded in the case of sorghum green manuring and it was similar to the sesbania green manuring, which had a weed density of 40.5m^{-2}. The decline in weed population may be due to the allelopathic effect of pre-flowering incorporation of sorghum green manuring. The maximum weed density of 46.5m^{-2} was recorded in the green manure free plot.

Similarly, the weed control methods have significant effect on the weed population of prevailing weed species in wheat. The lowest weed density of 18.8m^{-2} was found in plots (WCM_6) (buctril super @ 750ml ha^{-1} + tharphali) followed by the WCM_7 (Isoproturon @

Table 2: Effect of Green Manuring and Weed Control Methods on Weed Density, Weed Dry Weight and Weed Control Efficiency

Treatments	Weed Density (m^{-2})	Weed Biomass (g m^{-2})	Weed Control Efficiency (%)
Green Manuring			
GM_1	46.5a	23.7a	48.2c*
GM_2	39.0b	17.4c	57.7a
GM_3	40.5b	19.8b	52.1b
Weed Control Methods			
WCM_1	19.2a	40.7a	0.0m
WCM_2	42.0c	21.4b	51.2d
WCM_3	22.1d	14.3d	67.4b
WCM_4	23.8d	16.1c	63.2c
WCM_5	46.7b	21.9b	50.2d
WCM_6	18.8e	12.7e	71.1a
WCM_7	21.4de	15.1cd	65.4bc

*Any two means not shearing a letter in common in column and row differ significantly at 5% probability level.

Where: GM_1= Without green manurimg, GM_2= Sorghum, GM_3= Sesbania, WCM_1= Control, WCM_2= Hand hoeing, WCM_3= Buctril Super @ 750ml ha^{-1}, WCM_4= Isoproturon 50 WP @ 1.00kg a.i. ha^{-1}, WCM_5= Thraphli, WCM6 = Thraphli + Bucrail Super @ 750ml ha^{-1}, WCM_7= Thraphli + Isoproturon 50 WP @ 1.00kg a.i. ha^{-1}.

1.00kg a.i. ha^{-1} + tharphali) with a recorded weed density of 21.4 m^{-2}. Both of the weed control methods (WCM_6 and WCM_7) were statistically similar to each other, but significantly differed from the rest of the weed control methods. The application of buctril super @ 750ml ha^{-1} showed better performance at suppressing the weed density (22.1m^{-2}). The 76% decrease in the weed density with applications of buctril super was reported by Sharif *et al.* [12]. The maximum weed density of 119.2m^{-2} was noted in the WCM_1.

The reason of reduced weed density in wheat was probably due to decomposition of green manure residues which released the phytotoxins and thus significantly inhibited the weed seed germination and growth. Similar results have been reported by Sarrantonio and Gallandt [10]. The findings are in correspondence with the study of Teasdale and Mohler [13], who described that weed seed emergence, is physically hindered by green manure residues. The results are in accordance with the work of Cheema and Khaliq [14], who also recorded concluded that 40.8% decrease in weed density was recorded with the incorporation of sorghum live mulch for weed management in wheat. The results are correlated with the findings of Ashiq *et al*. [15], who reported that the weed density significantly decreased through the application of herbicides.

3.1.2. Weed Biomass (g m^{-2})

The weed dry biomass accumulation is an applicable parameter for evaluating the antagonistic nature of weeds for resource utilization and to compete with crop plants. The weed biomass was significantly reduced by all the weed control methods followed after the incorporation of sorghum and sesbania green manuring (Table **2**). The green manuring significantly decreased the dry matter production of weeds. The lowest weed biomass of 17.4gm^{-2} was recorded from the plots where sorghum green manure was practiced followed by the sesbania live mulch incorporation (19.8gm^{-2}). The maximum weed biomass of 23.7gm^{-2} was noted in the green manure free plots.

The lowest weed dry weights, owing to release of phytotoxins during decomposition of green manure crops, supressed the weeds. Similar results have been reported by Bhadoria [16]. The results are in accordance with the study of Czarnota *et al.* [17], who described that “Sorgoleone”, an allelochemical release from the roots of sorghum, sufficiently retards weed growth and ultimately reduced the weed dry biomass.

Similarly, all the weed control methods affected the weed dry biomass. The minimum weed dry matter of 12.7g m^{-2} was recorded in plots where WCM_6 followed by the WCM_3 and WCM_7 with weed dry biomass of 14.3g m^{-2} and 15.1g m^{-2}, respectively. These weed control methods (WCM_6, WCM_3 and WCM_7) were statistically similar to each other, but differed significantly compared to other weed control methods. The maximum decline in weed dry biomass was attributed to the application of post emergence herbicides. The results are in agreement with the findings of Zahoor *et al.* [18], who reported that the application of buctril super significantly reduced the weed dry weight. The highest weed biomass of 40.7g m^{-2} was obtained in the weedy check plots (WCM_1).

The results are in line with the study of Amare *et al.* [19], who reported that application of isoproturon @ 1.00kg ha^{-1} significantly reduced the weed dry weight in wheat. The findings of this study are correlated with the work of Creamer and Baldwin [20], who reported 94% decline in weed biomass with sorghum green manuring grown for weed management compared to control without green manuring.

3.1.3. Weed Control Efficiency (%)

The examination of data pertaining to weed control efficiency, presented in Table **2**, showed statistically significant effect. The green manure grown as a part of integrated weed management represented a considerable increase in the weed control efficiency. The highest weed control efficiency of 57.7% was recorded from the plot where sorghum green manure was incorporated followed by the sesbania green manuring (52.1%). The lowest weed control efficiency of 48.2% was recorded from green manure free plots.

Similarly, all the weed control methods showed significant difference in the weed control efficiency of various tested treatments in wheat. The highest weed control efficiency of 71.1% was recorded in WCM_6 followed by the WCM_3 (67.4%). Both of the weed control methods (WCM_6 and WCM_3) were statistically similar to each other, but extensively differed from the rest of the weed control methods. The WCM_7 (65.4%) showed better performance in response to weed control efficiency followed by the WCM_4 (63.2%). The minimum weed control efficiency was measured in the WCM_5 (50.2%).

The incorporation of sorghum green manure and the application of post emergence herbicides significantly reduced the weed dry weight, ultimately increases the weed control efficiency. The results are correlated with the study of Hossain *et al.* [21], who documented that application of post emergence herbicides reduced the weed dry weight and consequently drastically increased weed control efficiency in wheat. The results are in accordance with the work of Singh *et al.* [22] who reported that maximum weed control efficiency was obtained with the use of herbicides in wheat. The results are in agreement with the finding of Amare *et al.* [19] who reported that application of isoproturon @ 1.00kg a.i. ha^{-1} significantly reduced the weed dry biomass, which ultimately increased the weed control efficiency in wheat.

3.2. Effect of Various Treatments on Yield and Yield Components of Wheat

3.2.1. Spike Length (cm)

Spike length influenced the grains per spike and consequently affected the grains yield of the wheat crop. Statistical analysis of data showed that spike length of wheat was significantly affected by all the weed control measures fallowed after green manuring (Table **3**).

The perusal of data on the effect of green manuring indicated that the highest spike length of 9.42cm was noted in the experimental plots where the incorporation of sorghum green manure was done followed by sesbania green manuring, which resulted in the spike length of 9.40cm. The sorghum and sesbania green manuring were statistically similar to each other but differed significantly for the spike length of 8.35cm from the green manuring free plots. This may be due to the incorporation of green manure residues, which physically and chemically supressed the weeds as reported by Xuan *et al.* [23], and contributes to more translocation of photosynathes and thus increased the spike length of wheat. Similar results have been reported by Borras *et al.* [24].

The examination of data showed that weed control methods significantly increased the spike length of wheat. The maximum spike length of 10.13cm was measured from the experimental plots where buctril super @ 750ml ha^{-1} (WCM_3) was applied followed by weed control method which was the integration of buctril super @ 750ml ha^{-1} + tharphali (WCM_7), resulting spike length of 9.81cm. Both of the weed control methods were statistically similar to each other but varied significantly from rest of the weed control methods. The lowest spike length of 7.95cm was recorded in the weedy check (WCM_1).

The combined effect of allelopathic residues and application of post emergence herbicides significantly reduced the weed infestation and in consequence produced less weed-crop competition for essential plants nutrients. The results are in line with the findings of Jabran *et al.* [25], who reported that application of buctril super @ 450g a.i. ha^{-1} considerably increased the spike length of wheat. The findings are in accordance with the work of [26], who concluded that longer spikes were produced in wheat by the application post-emergence herbicides. The results are also similar to the study by Cheema and Khaliq [14], who reported that the incorporation of sorghum significantly increased the spike length of wheat.

3.2.2. Number of Spikelet Per Spike

The perusal of data, presented in Table **3**, showed the significant effect of green manuring and different weed control methods on the number of spikelets $spike^{-1}$ of wheat. The green manuring significantly increased the number of spikelets $spike^{-1}$. The highest number of spikelets $spike^{-1}$ of 16.14 was recorded in sesbania green manuring followed by sorghum green manuring (15.85). Both of the green manure treatments was statistically similar to each other but differed significantly from the green manure free plots (13.33). The increase in the number of spikelets $spike^{-1}$ in sesbania green manuring may be due to more availability of nitrogen to wheat crop and resulting reduction in weed infestation. Similar results have been reported by Caamal-Maldonado *et al.* [27], who reported that legume green manures significantly reduced the weeds in subsequent cash crops.

The weed control methods significantly increased the number of spikelets $spike^{-1}$ of wheat. The highest number of spikelets $spike^{-1}$ of 17.23 was recorded from WCM_3 followed by WCM_6 (16.89). Both weed control methods (WCM_3 and WCM_6) were statistically similar to each other but differed significantly from rest of the weed control methods. The lowest number of spikelets $spike^{-1}$ of 12.66 was noted in the inter-hoeing (WCM_5) followed by the weedy check (WCM_1), resulting in 12.67 spikelets $spike^{-1}$. The better performance of WCM_3 and WCM_6 as compared to other weed control methods could be probably owing to effective weed suppression responsible for good crop stand and thus increased in the number of spikelets $spike^{-1}$. Similar results have been reported by Cheema *et al.* [14].

The application of herbicides significantly retards the weed growth and legumes green manure incorporation increased the nutrient availability for better crop production and ultimately resulted in increased number of spikelets spike^{-1}. The findings are supported by the study of Hartwig and Ammon [28], who concluded legume cover crops have the potential to suppress the weed.

3.2.3. Number of Grain Per Spike

The effect of green manuring and different weed control methods on number of grains spike^{-1} was significant. The data pertaining to grains spike^{-1} are presented in Table **3**. The grains spike^{-1} was significantly affected by sorghum and sesbania green manuring. The maximum number of grains spike^{-1} of 41.95 was recorded from the experimental plots where sorghum green manuring was incorporated followed by sesbania green manuring with the grains spike^{-1} of 39.52, both of the green manures were statistically similar to each other but differed significantly in the number of grains spike^{-1} (36.38) from plots without green manuring. This might be possibly due to soil incorporation of sorghum green manure successfully reduced the population and dry matter production of weeds and ultimately increased in the production of grains spike^{-1} in wheat. The results are correlated with study of Ahmad *et al.* [29].

Similarly, the number of grains spike^{-1} was affected by different weed control methods. The effect of all the weed control methods illustrated statistically significant differences for the number of grains spike^{-1}. The maximum number of grains spike^{-1} (44.34) was recorded in WCM_3 followed by WCM_7 the resulted in grains spike^{-1} of 43.45. These weed control methods were statistically similar to each other but differed significantly from all the weed control methods. The lowest number of grain per spike (29.11) was measured in the weedy check (WCM_1).

The increase in the number of grains spike^{-1} was possibly attributed to more weed suppression, which ultimately enhanced the translocation and accumulation of photosynathates to grain formation in the wheat [24]. These findings are in accordance with the study of Iqbal [30], who reported an increase in the number of grains spike^{-1} with the application of board spectrum post emergence herbicides. The results are correlated with findings of Awan *et al.* [31], who reported that the allelopathic water extract of sorghum, used for weed suppression in wheat, significantly enhanced the grains spike^{-1}.

3.2.4. 1000-Grains Weight (g)

Statistical analysis of data indicated that the 1000-grain weight of wheat was significantly affected by all the weed control methods following the incorporation of sorghum and sesbania green manures (Table **3**). The main effect of green manuring revealed that the maximum 1000-grain weight of 41.70g was achieved from the experimental plot where sorghum green

Table 3: Effect of Green Manuring and Weed Control Methods on Yield Components of Wheat

Treatments	Spike Length (cm)	No. of Spikelet Spike^{-1}	No. of Grain Spike^{-1}	1000-Grain Weight (g)	Grain Yield (kg ha^{-1})
Green Manuring					
GM_1	8.35b	13.33b	36.38c	36.4c	2381.6c
GM_2	9.42a	15.85a	41.95ba	41.7a	2944.3a
GM_3	9.40a	16.14a	39.52a	39.7b	2735.9b
Weed Control Methods					
WCM_1	7.95e	12.67d	29.11e	31.3d	1835.3e
WCM_2	9.01bc	14.65c	38.11c	36.4c	2433.0c
WCM_3	10.13a	17.23a	44.34a	42.6b	2963.6b
WCM_4	8.71cd	15.77bc	42.34b	41.5b	3016.1b
WCM_5	8.47d	12.66d	34.67d	36.5c	2154.7d
WCM_6	9.81a	16.89ab	43.00ab	44.5a	3208.5a
WCM_7	9.33b	15.88bc	43.45ab	42.1b	3199.8a

*Any two means not shearing a letter in common in column and row differ significantly at 5% probability level.

Where, GM_1= Without green manurimg, GM_2= Sorghum, GM_3= Sesbania, WCM_1= Control, WCM_2= Hand hoeing, WCM_3= Buctril Super@750ml ha^{-1}, WCM_4= Isoproturon 50 WP @ 1.00kg a.i. ha^{-1}, WCM_5= Thraphli, WCM6 = Thraphli + Bucrail Super @ 750ml ha^{-1}, WCM_7= Thraphli + Isoproturon 50 WP @ 1.00kg a.i. ha^{-1}.

manure was incorporated followed by sesbania green manure with the obtained 1000-grain weight of 39.76g. The minimum 1000-grain weight was attained from plot where no green manure was practiced.

Similarly, effects of all the weed control methods have significant effect on 1000-grain weight of wheat. The maximum 1000-grain weight of 44.59g was found in experimental plots where buctril super @ 750ml ha^{-1} + tharphali (WCM_6) was applied followed by the sole application of buctril super @ 750ml ha^{-1} (WCM_3) the attained grain weight of 42.60g. These weed control methods were statistically similar to isoproturon @ 1.00kg a.i. ha^{-1} + tharphali (WCM_7), with the resulting grain weight of 42.14g and isoproturon @ 1.00kg a.i. ha^{-1} (WCM_4) with the grain weight of 41.56g. The minimum 1000-grain weight of 31.31g was measured in the weedy check (WCM_1) followed by the hand hoeing (WCM_2) which attained a grain weight of 36.44g.

The possible reason behind the highest 1000-grain weight might be that the decline in weed infestation provided suitable environmental conditions for crop growth and development. The results are consistent with findings of Cheema and Khaliq [32], who reported that 1000-grian weight was increased by sorghum stalk incorporation @ 6Mg ha^{-1} and by the applications of Bromoxynil + MCPA @ 1.2 L ha^{-1} and Isoproturon @ 2.0kg a.i. ha^{-1}. The results are also coordinated with the study of Mushtaq *et al.* [33], who documented that the 1000-grain weight was increased with the minimum weed invasion.

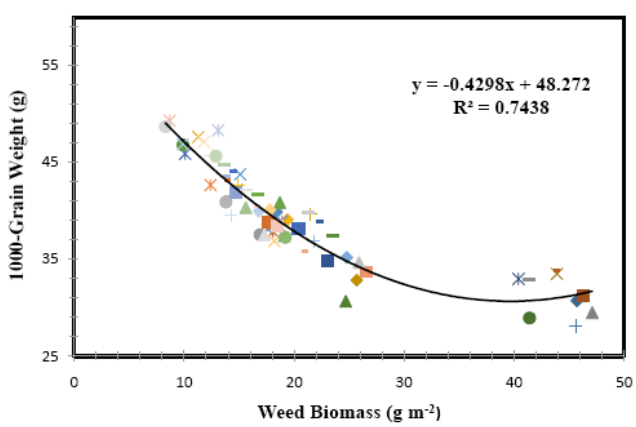

Figure 1: Relationship between 1000-grain weight and weed biomass.

3.2.5. Grains Yield (kg ha^{-1})

Grain yield is a contribution of its yield related parameters particularly, 1000-grain weight. Further-more, in rainfed area the grain yield of wheat is essentially dependent on the timely availability of soil moisture. The perusal of data Table **3** regarding grain yield collected in response to different weed control methods fallowed after the incorporation of sorghum and sesbania fresh residue depicted that all the weed management practices have significant effect on grain yield of wheat in both green manures.

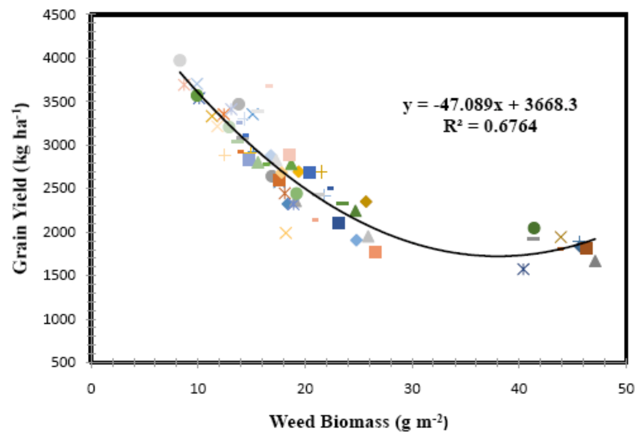

Figure 2: Relationship between grain yield weed biomass.

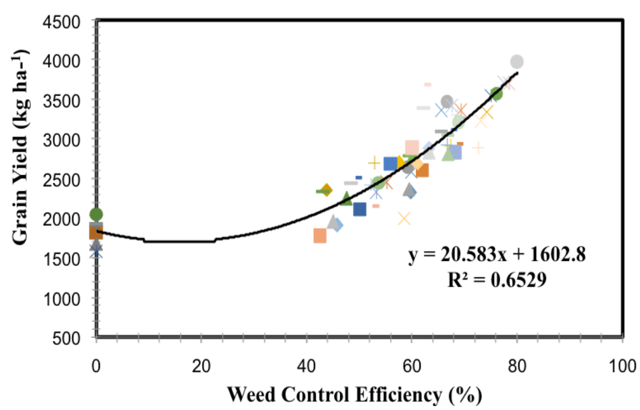

Figure 3: Relationship between grain yield and weed control efficiency.

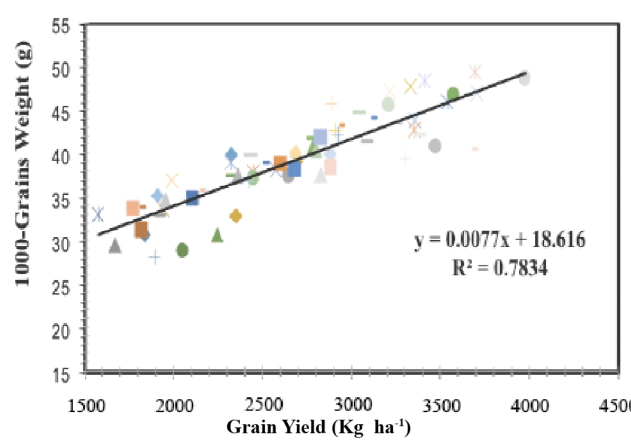

Figure 4: Relationship between 1000-grain weight and grain yield.

Table 4: Partial Budgeting, Weed Management by Sorghum Green Manure and Different Weed Control Methods in Wheat. Grain Yield Value, PKRs. = 31.25kg^{-1}

Particulars	Sorghum Green Manuring						
	WCM_1	WCM_2	WCM_3	WCM_4	WCM_5	WCM_6	WCM_7
Average Yield (Kg ha^{-1})	1855.9	2555.4	3481.6	3393.9	2252.8	3791.5	3279.3
Adjusted Yield (Kg ha^{-1})	1670.4	2299.9	3133.5	3054.6	2027.6	3412.4	2951.4
Gross Field Benefit (PRs ha^{-1})	52200	71871	97921	95456	63362	106637	92231
Cost of Herbicides	0	0	1400	940	0	1400	940
Cost of Herbicides Application	0	0	1520	1520	0	1520	1520
Cost of Labor of Hand Hoeing	0	3600	0	0	0	0	0
Cost of Labor for Tharphali Application	0	0	0	0	4000	4000	4000
Total Cost that Vary (PRs ha^{-1})	0	3600	2920	2460	4000	6920	6460
Net Benefit (PRs ha^{-1})	52200	68271	95001	92996	59362	99717	85771

During the experimentation the grain yield of wheat was significantly influenced by the main effect of green manuring. The maximum grain yield of 2944.3kg ha^{-1} was recorded in the case of sorghum green manure followed by sesbania green manure which produce grain yield of 2735.9kg ha^{-1}. The minimum grain yield of 2381.6kg ha^{-1} was noted in green manure free plot.

Similarly, all the weed control methods indicated statistically significant differences in the grain yield of wheat. The highest grain yield of 3208.5kg ha^{-1} was achieved in WCM_6 (buctril super @ 750ml ha^{-1} + tharphali) followed by WCM_7 (isoproturon @ 1.00kg a.i. ha^{-1} + tharphali) the acquired grain yield of 3199.8kg ha^{-1}. The lone application of buctril super (WCM_3) and isoproturon (WCM_4) also performed better to enhancing the grain yield of wheat, both was statistically similar, but they were significantly differed from the rest of weed control methods. The lowest grain yield of 1835.3kg ha^{-1} was noted in the weedy check plots (WCM_1).

The highest grain yield may be due to the suppression of weed by the allelopathic potential of sorghum at the initial stages of wheat growth with the consequences of less weed-crop competition for nutrient and soil moisture. These findings are supported by the study of Cheema and Khaliq [32] who stated that the incorporation of sorghum fresh residue significantly enhanced the grain yield of wheat. The results are consistent with the work of Amare *et al.* [19] who documented that increases in grain yield with the application of isoproturon for weed management. The results are also correlated with the finding of Khalil *et al.* [34] who reported that the application of buctril super significantly increased the grain yield of wheat. Similar results are documented by Malik *et al.* [35] and Jabran *et al.* [25], they concluded that grain yield of wheat considerably increased by the application of bromoxynil + MCPA.

4. ECONOMIC ANALYSIS

The partial budgeting and marginal analysis of different weed control methods under sorghum green manure practices were performed as suggested by CIMMYT [36] given in Table **4** and graphically shown in Figure **5**, respectively. The maximum net benefit of PKRs. 99717 was obtained from plots where buctril super @ 750ml ha^{-1} along with tharphali (WCM_6) was

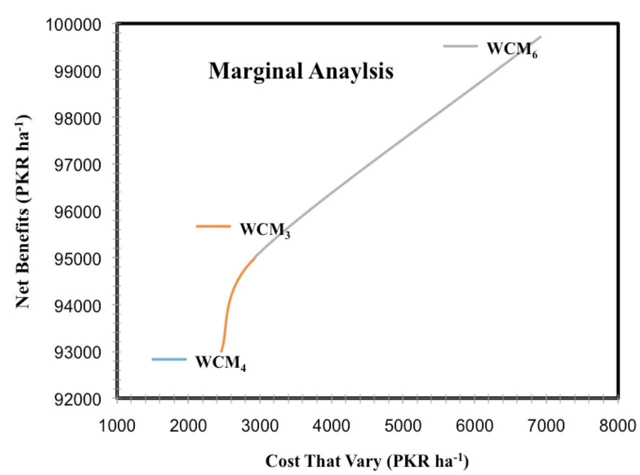

Figure 5: Marginal analysis of different weed control method under sorghum green manure practices in wheat.

applied while; the minimum net benefit of PKRs. 52200 was achieved from weedy check plots (WCM_1) in case of sorghum green manure.

5. CONCLUSION

It may be concluded that the incorporation of sorghum green manure and the use of herbicides were proven to be economically and ecological safe weed management strategy in rain-fed wheat. The integration of summer green manure with post emergence herbicides significantly reduced weed density and biomass and ultimately increased the yield of wheat. The sesbania green manure incorporation enriched the nutrients of soil for following cash crop but not significantly retard the germination and biomass of weeds of wheat.

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