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Correlation analysis of growth, yield and yield components of wheat (*Triticum aestivum*) under varying weed densities

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ABSTRACT

A study was carried out at Student's Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during *rabi* 2010-11 and 2011-12. The experimental site was sandy loam, with normal soil pH and electrical conductivity, low in organic carbon and available N and medium in available P and K. The investigation consisted of 11 treatments each having different population levels of button weed (*Malva neglecta)* and kandyali palak *(Rumex spinosus),* viz 0,3,6,9,12 plants/m^2 and two treatments having pure populations of each weed. Wheat crop accumulated more heat units (AGDD, AHTU, APTU) during the year 2011-12 as compared to the crop year 2010-11. Increase in population levels of both weed species significantly decreased the crop growth rate (CGR) and relative growth rate (RGR) of wheat crop. The results showed a significant decrease in number of tillers, effective tillers, number of grains/ear, 1 000-grain weight and grain yield of wheat with increasing population densities of *Malva neglecta* and *Rumex spinosus* (from 3 to 12 plants/m^2). Highest grain yield of wheat (57.54 q/ha) was recorded under pure wheat treatment and lowest grain yield was recorded in treatments T_5 and T_{10} having 12 plants of *Malva neglecta* and *Rumex spinosus,* respectively. Highest heat use efficiency (HUE) was recorded in pure wheat treatment in contrast to all other treatments. Determination of correlation matrix revealed that crop yield was perfectly negatively correlated with population densities of *Malva neglecta* and *Rumex spinosus* while there was highly significant direct relationship with other crop growth parameters like dry matter accumulation, LAI, tiller number/m^2, effective tillers/m^2, ear length, and number of grains/ear etc. Regression analysis interpreted positive relation of grain yield with growth parameters and negative with both weed population densities. From the study it was concluded that higher weed infestation enhances inhibitory influence on the growth rate, heat use efficiency and yield of wheat crop.

Key words: Correlation matrix, Crop growth rate, Heat units, *Malva neglecta*, *Rumex spinosus,* Wheat, Yield

Wheat (*Triticum aestivum* L.) is an important cereal crop of Indo-Gangetic plains of India in general and Punjab in particular. During the Green Revolution introduction of short statured wheat varieties aided with improved production and protection technologies caused a remarkable boost in overall productivity of wheat. These varieties responsive to irrigation and fertilizer application not only resulted in elevating overall productivity but also created ecological conditions favorable for the growth and development of weeds. The population pressure of weeds has great impact on grain yield as reported by Mehra and Gill (1988) and as they reported a reduction of 7.6- 44.2% in grain yield of wheat with increase in weed population from 50 to 200 plants/m^2. Weeds are undesirable plants, which infest different crops and inflict negative effect on their yield. There are innumerable reports on the inhibitory effects of weeds on crop plants (Javeid *et al.* 2007). Among various weed species, two broad leaf weeds namely *Malva neglecta* and *Rumex spinosus* are going to be a threat to successful crop management. *Malva neglecta* is a broad leaf weed belonging to family Malvaceae and is commonly known as button weed, little mallow, dwarf mallow, cheese weed. It mainly infests the roadside areas in large patches, but the infestation of *Malva neglecta* in crops like wheat is going to be a major problem in these days. *Malva neglecta* can be winter annual or biennial plant and reproduces only from seed. A single plant can bear a large number of small button like fruits in which seeds are enclosed. *Rumex spinosus* belongs to family *Polygonaceae*, is an annual plant which also reproduces from seeds. Commonly it is known as 'Dock/ Sorrel'. Due to wider adaptability and prolific growth rate they compete for growth factors like water, nutrients etc and reduce the crop yield. Spiny coat of seeds helps in better dispersal and also acts as constraint in various inter-cultural operations like fertilizer application, irrigation etc. in field due to spiny seeds. The infestation of broad leaf weeds in wheat crop may lead to the reduction of grain yield to the tune of 20-30% (Wilson and Cussans, 1984). Therefore, the present experiment was undertaken to understand the

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influence of these two broad leaf weeds on the growth and yield of wheat crop.

MATERIALS AND METHODS

The experiment was conducted during year 2010-11 and 2011-12 at Punjab Agricultural University, Ludhiana. Ludhiana is located in Trans-Gangatic agro-climatic zone and represents the Indo-Gangatic alluvial plains. It is located in 30^{o}56' N latitude and 75^{o}52' E longitude at an altitude of 247 m above the MSL. Ludhiana is characterized by sub-tropical semi-arid type of climate with hot summer and cold winters. The soil of the experimental site was sandy loam having 172.7, 12.1, 144 kg/ha of available N, P and K, respectively and pH 7.6. The experiment was laid out in Randomized Complete Block Design (RCBD) with 11 treatments, viz. T_1, pure wheat crop; T_2, 3 plants of *Malva neglecta*/m^2; T_3, 6 plants of *Malva neglecta* /m^2; T_4, 9 plants of *Malva neglecta* /m^2; T_5, 12 plants of *Malva neglecta* /m^2; T_6, Pure *Malva neglecta* ; T_7, 3 plants of *Rumex spinosus* /m^2 ; T_8, 6 plants of *Rumex spinosus* /m^2 ; T_9, 9 plants of *Rumex spinosus* /m^2 ; T_{10}, 12 plants of *Rumex spinosus* / m^2 ; T_{11}, Pure *Rumex spinosus,* and replicated four times. Sowing of wheat variety PBW 550 was done on November 13, 2010 and November 16, 2011 with *Kera* method using seed rate of 112.5 kg/ha. All crop management practices were performed as per recommandation of Punjab Agricultural University. The fertilizers were applied at the rate of 125 kg N/ha, 50 kg P_2O_5/ha and 30 kg K_2O/ha through urea, DAP and muriate of potash. Half the dose of nitrogen and full dose of phosphorus and potassium was applied at the time of sowing by broadcasting method. Remaining half nitrogen was applied by top dressing after first irrigation. The experimental units were charged with seeds of *Malva neglecta* and *Rumex spinosus* according to the requirement of different weed density treatments on the same day, i.e. November 13, 2010 and November 16, 2011 by broadcasting method. To maintain pure wheat stand in T_1 treatment, weeds were removed manually and use of herbicides was omitted for weed management. Growth parameters of crop like plant height, dry matter accumulation, leaf area index (LAI), number of tillers and yield contributing characters like effective tillers, ear length, number of grains/ear were recorded periodically during the crop growth cycle. To study the impact of weed population on growth of wheat crop, growth indices like crop growth rate (CGR), relative growth rate (RGR) were calculated as follow:

Crop growth rate (CGR) = W_2-W_1/t_2-t_1 (Briggs *et al.* 1920)

Relative growth rate (RGR) = (logW_2-logW_1)/t_2-t_1 (Briggs *et al* 1920)

where, W_1-weight accumulation at time t_1, W_2-weight accumulation at time t_2.

Growing degree days (GDD)

$$GDD=\sum [(Tx+Tn)/2]- \text{Base temperature}$$

where, T_x= Daily maximum temperature, T_n=Daily minimum temperature.

Accumulated photothermal units (APTU) = $\sum$ GDD×N where, N= maximum possible sunshine hours.

Accumulated heliothermal units (AHTU) = $\sum$ GDD×n where, n= actual sunshine hours.

Phenothermal units (PI)

$$PI= GDD \div \text{Days between two growth stages}$$

Heat use efficiency (HUE)

$$HUE= \text{Grain yield} \div AGDD$$

Correlation matrix, scatter plot diagrams and regression equations were determined for both the years. Correlation was expressed between grain yield and LAI at 90 DAS, tiller number/m^2 at 120 DAS, effective tillers/m^2, ear length, number of grains/ear. All the data was subjected to analysis of variance (ANOVA) for RCBD using SAS 9.3 software packages. The meteorological data on weather elements was recorded at meteorological observatory of university during 2010-11 and 2011-12. From the collected data, mean values of all weather elements between different growth stages of the crop were calculated.

RESULTS AND DISCUSSION

Heat units

The heat unit or GDD was proposed to explain the relationship between growth duration and temperature. This concept is based on the assumption that there exists a direct and linear relationship between growth and temperature. Data pertaining to GDD, HTU and PTU is presented in Table 2. It was observed that wheat crop accumulated different heat units during the year 2010-11 and 2011-12 to attain different growth stages. The differential behaviour of crop was due to difference in weather conditions and hence in time period to attain different crop growth states during both the years. Up to maturity, wheat crop accumulated more heat units during the year 2011-12 as compared to 2010-11 which was due to longer duration of crop in second year than 2010-11. The crop consumed AGDD, AHTU and APTU of 1796.3 (^{o}C day), 13716.4 (^{o}C day hr) and 23865.3 (^{o}C day hr), respectively during 2010-11 and 1796.6 (^{o}C day), 15741.1 (^{o}C day hr) and 26367.4 (^{o}C day hr), respectively during 2011-12. The phenothermal index, expressed as degree day per growth day, was observed higher during the year 2011-12 than 2010-11 at all growth stages except at booting stage. It was due to increase in time taken to reach at booting stage. These findings are in conformity with the results of Bhat *et al.* (2015) who reported that with increase in duration of crop/crop variety, accumulation of heat units increases than shorter duration. Any variation in length of period taken for any growth stage, causes variation in level of heat unit accumulation as well as PTI value.

Growth indices

Crop growth rate

Crop growth indices, viz. CGR and RGR represents

Table 1 Heat unit accumulation by wheat crop during 2010-11 and 2011-12

Stage	AGDD (°C day)		AHTU (°C day hr)		APTU (°C day hr)		PTI (°C day/day)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Emergance	126.8	119.6	761.72	460.56	1301.911	1277.256	15.85	17.09
CRI	274.25	317.05	1968.95	1626.4	3146.068	3627.48	21.09	21.14
Tillering	371.05	409.95	3015.37	2757.28	4681.975	5326.232	33.73	37.27
Jointing	701.5	740.55	6249.94	7095.36	11774.6	13074.58	13.75	14.81
Booting	833.45	834.25	6914.39	8475.52	13581.8	15264.3	69.45	64.17
Flowering	899.35	902.55	7813.74	9329.76	14659.55	16474.22	128.48	128.94
Milk stage	1053.35	1073.1	8867.09	11092.96	16881.14	18960.18	75.24	82.55
Dough stage	1215.65	1219.95	10082.74	12199.52	18518.98	20791.02	121.57	121.99
Harvest maturity	1796.3	1796.55	13716.44	15741.12	23865.26	26367.44	57.94	61.95

the rate of crop growth and rate of crop growth per unit dry matter respectively. The data collected on dry matter accumulation of crop was used to determine CGR and RGR which is shown in Table 2 and 3. From 60-90 DAS, pure wheat treatment (T_1) recorded significantly higher CGR than rest of the treatments except treatment with 12 plants of *Rumex spinosus* /m^2. Crop growth rate recorded at 90-120 DAS was significantly higher in pure wheat treatment and it was statistically at par with treatments containing 3 plants of *Malva neglecta* and *Rumex spinosus*/m^2, respectively. It might be due to less competition of weeds and crop because of presence of only 3 plants/m^2 each of *Malva neglecta* and *Rumex spinosus* (Table 2). With further increase in weed population density from 3 to 12 plants/m^2, a significant decrease was observed in crop growth rate during the interval 120 DAS to crop maturity. Data collected on dry matter accumulation by wheat crop was analysed to determine relative growth rate (RGR) between crop growth stages, viz. 60-90 DAS, 90-120 DAS and 120 DAS-harvest stage (Table 3). Results showed a significant decrease in RGR of crop with increase in weed population levels. Between growth stage 90-120 DAS, RGR of pure wheat treatment was at par with treatments containing 3 plants/m^2 of *Malva neglecta* and *Rumex spinosus*. Further increase in weed density resulted in significant decrease in wheat RGR. Results of wheat RGR between 120 DAS-harvest stage recorded significant difference between solid wheat stand and all other treatments. With increase in weed density from 3 to 12 plants/m^2 of *Malva neglecta* and *Rumex spinosus,* highly significant decrease in RGR was recorded. Baghestani *et al* (2006) in their experiment in Iran also reported a decrease in crop growth rate due to infestation of *Avena ludoviciana* and *Goldbachia laevigata*.

Table 2 Effect of *Malva neglecta* and *Rumex spinosus* on crop growth rate (g day^{-1}m^{-2}) of wheat

Treatment	60-90 DAS	90-120 DAS	120-Harvest
Pure wheat	9.9583	19.4000	3.3858
3 plants of *Malva neglecta*/m^2	9.2163	19.2250	0.4083
6 plants of *Malva neglecta*/m^2	9.2250	16.3750	0.4633
9 plants of *Malva neglecta*/m^2	9.3083	12.1333	1.0617
12 plants of *Malva neglecta*/m^2	9.5917	8.3896	0.7541
Pure *Malva neglecta*	0.0000	0.0000	0.0000
3 plants of *Rumex spinosus* /m^2	9.2750	19.2083	2.1567
6 plants of *Rumex spinosus* /m^2	9.2583	16.7333	0.3783
9 plants of *Rumex spinosus* /m^2	9.4500	11.8750	1.2791
12 plants of *Rumex spinosus* /m^2	9.5883	7.9000	1.1158
Pure *Rumex spinosus*	0.0000	0.0000	0.0000
LSD (P=0.05)	0.3770	0.8567	0.7377

Table 3 Effect of *Malva neglecta* and *Rumex spinosus* on relative growth rate (g/g/day) of wheat

Treatments	60-90 DAS	90-120 DAS	120-Harvest
Pure wheat	0.0133	0.012	0.0015
3 plants of *Malva neglecta*/m^2	0.0123	0.012	0.0003
6 plants of *Malva neglecta*/m^2	0.0130	0.010	0.0004
9 plants of *Malva neglecta*/m^2	0.0130	0.009	0.0006
12 plants of *Malva neglecta*/m^2	0.0148	0.007	0.0007
Pure *Malva neglecta*	0.0000	0.000	0.0000
3 plants of *Rumex spinosus* /m^2	0.0125	0.012	0.0010
6 plants of *Rumex spinosus* /m^2	0.0130	0.010	0.0003
9 plants of *Rumex spinosus* /m^2	0.0135	0.009	0.0008
12 plants of *Rumex spinosus* /m^2	0.0145	0.006	0.0006
Pure *Rumex spinosus*	0.000	0.000	0.0000
LSD (P=0.05)	0.0007	0.0009	0.0004

Growth parameter

Number of tillers

Number of tillers of wheat crop/m^2 observed a significant decrease in the number with increase in weed population/m^2 (Table 4). The increase in weed plant population caused increased competition between weeds and the crop for space and nutrients which resulted in reduction in tiller number of the crop. The highest tiller number was recorded in solid wheat stand and it was significantly higher than rest of the treatments. However, minimum number of tillers were recorded where the population of both weed specie was highest i.e. 12 plants/m^2. At 120 DAS, the treatments with 9 and 12 plants recorded 8.4, 10.9, 9 and 10.4% reduction in tiller number, respectively, by *Malva neglecta* and *Rumex spinosus* compared to solid wheat stand. Siddiqui *et al* (2010) reported about 33, 25 and 34% reduction in tiller number of wheat over control at 120 days after sowing by *Rumex dentatus*, *Chenopodium album* and *Medicago denticulata*, respectively.

Effective tillers

The number of effective tillers per unit area gives us the idea about the performance as well as competitive ability of the crop in a given treatment because more the number of effective tillers per unit area, better will be the performance of the crop and more competitive the crop is. With increase in weed density from 3 to 12 plants/m^2, there was a significant decrease in the number of effective tillers among all the treatments (Table 4). Highest number of effective tillers (491.75) was recorded solid wheat stand and lowest (401.0 and 406.25) in treatments having 12 plants/m^2 of *Malva neglecta* and *Rumex spinosus*, respectively. A reduction in number of effective tillers with 3 plants/m^2 of *Malva neglecta* and *Rumex spinosus* upto 5.8 and 5.9% and with 12 plants/m^2 up to 12.6 and 10.5 per cent was recorded. High weed density posed severe competition on the wheat crop resulted in less number of effective tillers/m^2. The results of decrease in number of effective tillers are in line with findings of Shehzad *et al.* (2012) who reported significantly lower spike bearing tiller number in wheat in weedy check treatment as compared to other treatments in which post-emergence herbicides were applied. Competition posed by weeds like *Phalaris minor*, *Convolvulus arvensis*, *Poa annua* etc. caused reduction in number of spike bearing tillers.

Table 4 Number of tillers/m^2 and effective tillers of wheat under different *Malva neglecta* and *Rumex spinosus* population densities

Treatment	60 DAS	90 DAS	120 DAS	Effective tillers/m^2
Pure wheat	496.75	495.25	495.50	491.75
3 plants of *Malva neglecta*/m^2	478.50	475.75	469.50	463.00
6 plants of *Malva neglecta*/m^2	470.00	464.75	460.75	451.00
9 plants of *Malva neglecta*/m^2	463.50	459.75	453.75	422.00
12 plants of *Malva neglecta*/m^2	452.75	448.25	441.00	401.00
Pure *Malva neglecta*	0.00	0.00	0.00	0.00
3 plants of *Rumex spinosus*/m^2	477.75	470.75	466.75	462.75
6 plants of *Rumex spinosus*/m^2	468.50	463.75	458.25	454.50
9 plants of *Rumex spinosus*/m^2	461.75	456.75	450.25	439.00
12 plants of *Rumex spinosus*/m^2	453.75	449.75	444.00	406.25
Pure *Rumex spinosus*	0.00	0.00	0.00	0.00
LSD (P=0.05)	5.66	5.53	5.69	6.13

Yield-attributing characters

The amount of economic yield depends upon the manner in which the net dry matter produced is distributed amongst different sinks of photosynthates. Solid wheat stand, with zero competition between crop and weeds, recorded the highest ear length (11.95) which was significantly greater than rest of the treatments. Presence of 3 plants/m^2 of *Malva neglecta* and *Rumex spinosus* resulted in 12.7 and 15.5% reduction in ear length and presence of 12 plants/m^2 caused 37.4 and 36.8% reduction in ear length, respectively, relative to the solid wheat treatment. A decrease in number of grains per ear of crop with increased weed population levels was recorded and highest number of grains/ear (42.25) was recorded in solid wheat stand which was significantly superior to rest of the treatments (Table 5). Lowest number of grains were recorded in treatments having 12 plants of *Malva neglecta*/m^2 and *Rumex spinosus*/m^2.

With increase in weed population density, shading effect as well as severe competition of weeds with the crop resulted in decreased number of grains per ear. These results support the findings of Plant *et al.* (1999). The data on 1 000-grain wt. of wheat revealed that increased weed plant population per unit area resulted in decreased 1 000-grain weight of the crop (Table 5). Maximum 1 000-grain weight was recorded in weed free treatment and it was significantly higher than rest of the treatments. Increased competition pressure of weeds on crop decreased the boldness of grains which resulted in decreased 1 000-grain weight. Treatments with 9 and 12 plants/m^2 each of *Malva neglecta* and *Rumex spinosus* resulted in 7.4, 10.5, 7.6 and 10.7% reduction in 1 000-grain weight, respectively, as compared to treatment pure wheat stand. Meisner *et al* (1992) also reported that the shrinkage of wheat grains due to the competition posed by different weeds species on the wheat crop was responsible for decreased 1 000-grain weight. Kaur *et al.* (2010 and 2013) reported that even presence of 15 plants/m^2 of *P. minor* and *Avena ludoviciana* resulted in significant decrease (10–14 %) in grain yield of wheat. Reduction in yield was mainly caused by the reduction in effective tillers, number of grains per spike and 1 000-grain weight.

Grain and straw yield

With the increase in infestation of both weed species from 0 to 12 plants/m^2 decrease in grain yield of wheat was observed (Table 5). Maximum grain yield was recorded in treatment where there was zero competition between

Table 5 Effect of *Malva neglecta* and *Rumex spinosus* on yield, yield attributing characters and heat use efficiency (HUE) of wheat

Treatment	Ear length (cm)	Grain/ear (No)	1000-grain wt (gm)	Grain yield (q/ha)	Straw yield (q/ha)	Harvest Index (HI)	HUE (%)
Pure wheat	11.95	42.25	40.38	57.54	60.82	0.49	3.2
3 plants of *Malva*/m^2 *neglecta*/m^2	10.43	39.60	39.18	50.65	56.13	0.48	2.82
6 plants of *Malva*/m^2 /m^2*neglecta*/m^2	9.60	38.10	38.10	47.06	50.24	0.48	2.62
9 plants of *Malva*/m^2 *neglecta*/m^2	8.55	37.20	37.38	40.29	45.30	0.47	2.24
12 plants of *Malva* m^2*neglecta*/m^2	7.48	35.18	36.15	32.38	40.22	0.45	1.8
Pure *Malva neglecta*	0.00	0.00	0.00	0.00	0.00	0.00	0
3 plants of *Rumex* /m^2 *spinosus*/m^2 /m^2	10.10	38.43	38.98	52.13	59.24	0.47	2.9
6 plants of *Rumex*/m^2 *spinosus*/m^2 /m^2	9.08	37.18	38.05	47.06	51.01	0.48	2.62
9 plants of *Rumex*/m^2 *spinosus*/m^2 /m^2	8.08	36.33	37.25	39.87	45.72	0.47	2.22
12 plants of *Rumex*/m^2 *spinosus*/m^2 /m^2	7.55	35.05	36.05	32.47	39.80	0.45	1.81
Pure *Rumex spinosus*	0.00	0.00	0.00	0.00	0.00	0.00	0
LSD (P=0.05)	0.40	1.04	0.58	1.39	1.89		

crop and weeds, which was significantly higher than rest of the treatments. The treatments having 6-12 plants of weeds/m^2 recorded a reduction of 18.21- 43.7% in grain yield as compared to weed free treatment. At higher weed densities there was greater degree of suppression of wheat plants which resulted in significant reduction in grain yield. Walia *et al.* (2001) also reported reduction of grain yield to an extent of 30 to 40% under different weed infestations as compared to weed free treatment. Similarly, a decrease in straw yield of wheat crop with increasing weed plant populations was noted. Increased competition between weeds and crop with increase in weed plant population per unit area caused decrease in plant height, number of tillers per unit area which resulted in decrease in straw yield of the crop. Highest straw yield was recorded in treatment solid wheat, which was superior to rest of the treatments. Table 5 also displays the data on heat use efficiency (HUE) of wheat crop as affected by variation in weed density in different treatments. Highest HUE was observed pure wheat treatment as compared to other treatments. Reduction in HUE was due to decrease in grain yield of crop due to hike in crop-weed competition with increase in weed population per unit area. Fig 1 and 2 displays graphical variation in grain yield of wheat with increase in number of weed plants/ m^2 of *Malva neglecta* and *Rumex spinosus,* respectively.

Correlation and regression

Testing of hypothesis concerning correlation between crop yield and growth parameters, viz. dry matter accumulation at maturity, plant height, LAI at 90 DAS, tiller number/m^2 at 120 DAS, chlorophyll index at 120 DAS, effective tillers/m^2, ear length, grains/ear, was also performed by calculating correlation matrix through principal component analysis in SAS 9.3 software packages (Table 6 and 7). The results revealed highly significant positive correlation of all parameters with wheat yield. The positive and significant correlation between growth and yield parameters and grain yield explains the true and direct

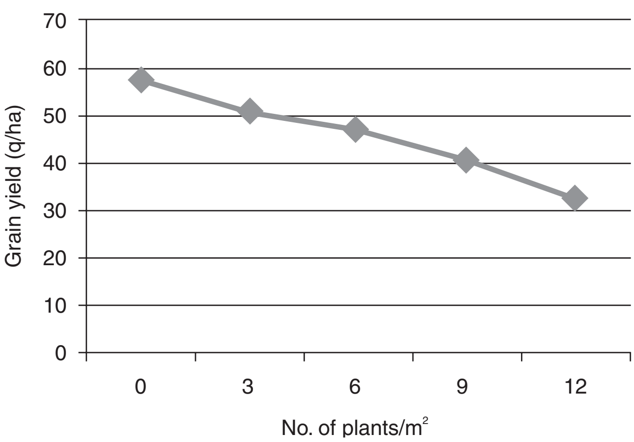

Fig 1 *Malva neglecta* population vs. grain yield

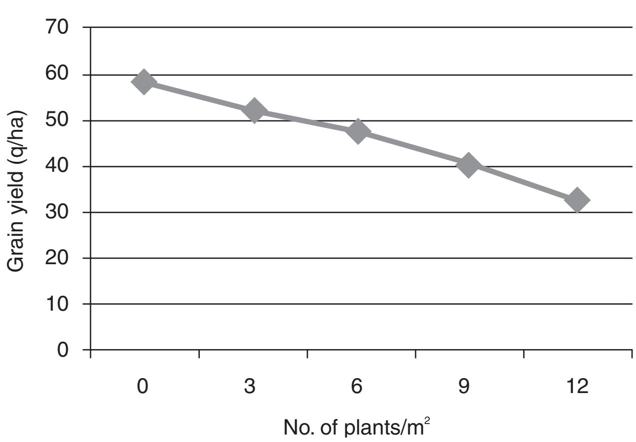

Fig 2 *Rumex spinosus* population vs. grain yield

Table 6 Correlation matrix between wheat crop yield, crop growth parameters and *Malva neglecta* population

	LAI	Plant height	DMA	Tiller number	Effective tiller	Chlorophyll index	Ear length	Grains/ear	Weed population	Wheat yield
LAI	1.000	0.955	0.996	0.972	0.972	0.983	0.997	0.987	-0.999	0.999
Plant height	0.955	1.000	0.935	0.988	0.978	0.978	0.964	0.972	-0.943	0.923
DMA	0.996	0.935	1.000	0.966	0.971	0.981	0.996	0.986	-0.998	0.998
Tiller number	0.972	0.988	0.966	1.000	0.999	0.997	0.985	0.994	-0.966	0.961
Effective tillers	0.972	0.9781=	0.971	0.998	1.000	0.997	0.986	0.995	-0.968	0.968
Chlorophyll index	0.983	0.978	0.990	0.997	0.997	1.000	0.993	0.999	-0.981	0.976
Ear length	0.997	0.964	0.996	0.984	0.986	0.993	1.000	0.995	-0.996	0.992
Grains/ear	0.987	0.972	0.986	0.994	0.995	0.999	0.995	1.000	-0.986	0.981
Weed population	-0.999	-0.943	-0.998	-0.966	-0.968	-0.981	-0.996	-0.986	1.000	-0.993
Wheat yield	0.999	0.9223	0.998	0.961	0.968	0.9762	0.992	0.981	-0.993	1.000

Table 7 Correlation matrix between wheat crop yield, crop growth parameters and *Rumex spinosus* population

	LAI	Plant height	DMA	Tiller number	Effective tiller	Chlorophyll index	Ear length	Grains/ear	Weed population	Wheat yield
LAI	1.000	0.964	0.990	0.949	0.947	0.957	0.985	0.955	-0.998	0.989
Plant height	0.964	1.000	0.924	0.998	0.990	0.991	0.993	0.998	-0.957	0.936
DMA	0.990	0.924	1.000	0.901	0.890	0.927	0.957	0.912	-0.995	0.997
Tiller number	0.949	0.998	0.901	1.000	0.999	0.984	0.988	0.998	-0.939	0.914
Effective tillers	0.947	0.998	0.899	0.999	1.000	0.984	0.986	0.9988	-0.938	0.913
Chlorophyll index	0.957	0.991	0.927	0.984	0.984	1.000	0.980	0.986	-0.958	0.947
Ear length	0.985	0.993	0.957	0.988	0.986	0.980	1.000	0.987	-0.978	0.959
Grains/ear	0.955	0.998	0.912	0.998	0.998	0.985	0.988	1.000	-0.948	0.925
Weed population	-0.998	-0.957	-0.995	-0.939	-0.938	-0.958	-0.978	-0.948	1.000	-0.996
Wheat yield	0.999	0.936	0.997	0.914	0.913	0.947	0.958	0.925	-0.996	1.000

relationship and these characters can be a major concern for agronomists and plant breeders. Scatter diagrams of LAI, tiller number, number of grains/ear and ear length showed positive relation with wheat yield (Fig 3,4,5 and 6). Grain yield of wheat was perfectly negatively correlated with population levels of *Malva neglecta* and *Rumex spinosus* which is clear from the Table 5 and scatter plot. Regression equation of LAI described that per unit change in LAI causes increase in grain yield by 13.34 times. Results of correlation coefficient are in line with findings of Petcu *et al* (2003) and Kaur *et al* (2016) in which they reported 0.71 value of r^2 between wheat yield and LAI. Sokoto *et al* (2012) determined correlation coefficient between grain yield and LAI, spike length, grains per spike which was 0.72, 0.49 and 0.49, respectively, and these were significant at 1% level of significance. In Regression analysis, grain yield is positively regressed to LAI, effective tillers/m^2 and ear length while it is negatively regressed with weed population levels. Regression equations show regression coefficients of 13.34, 0.37, 6.35, - 2.02 and – 2.08 of LAI, effective tillers, ear length, *Malva neglecta* and *Rumex spinosus*, respectively.

Grain yield and LAI : 0.02+13.34x
Grain yield and effective tillers/m^2 : 0.02+0.37x
Grain yield and ear length : 0.06+6.35x
Grain yield and *Malva neglecta* population levels : 57.72-2.02x
Grain yield and *Rumex spinosus* population levels : 58.29-2.08x

Regression equations of wheat crop yield with different crop growth parameters and weed populations (Fig 3 to 8).

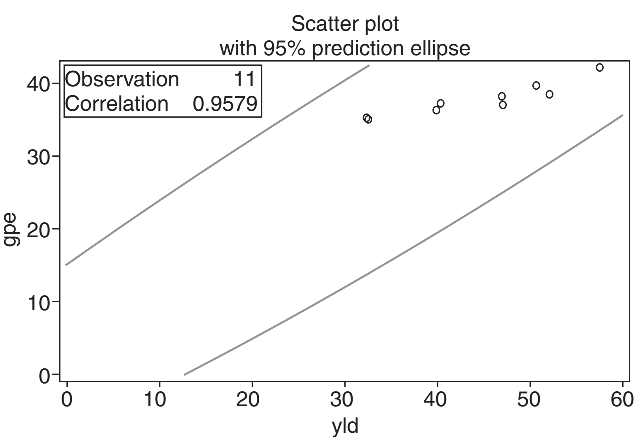

Fig 3 Grain yield and grains per ear

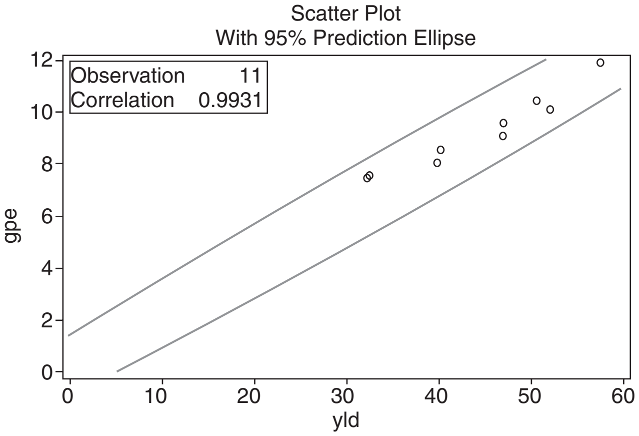

Fig 4 Grain yield and ear length

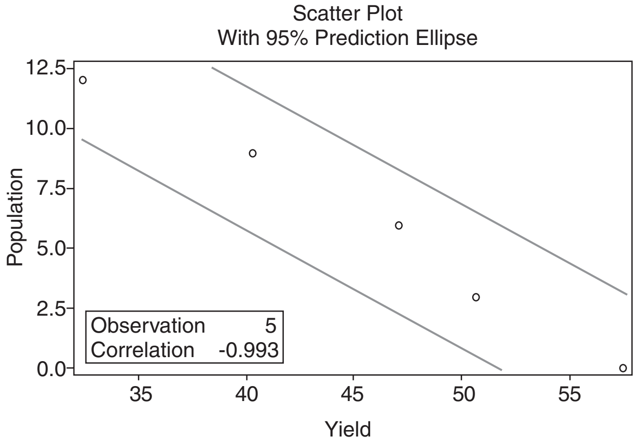

Fig 7 *Malva neglecta* population vs grain yield

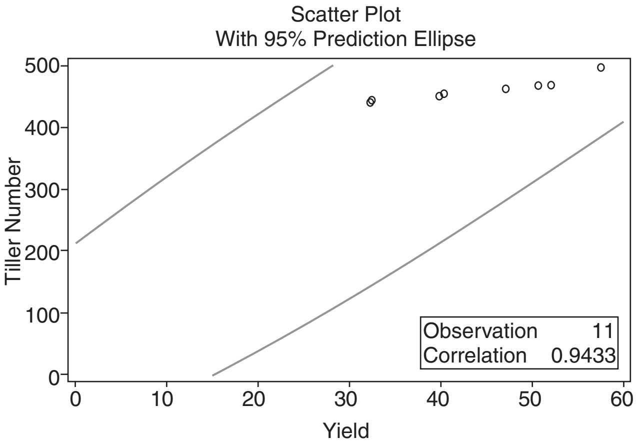

Fig 5 Grain yield and tiller number

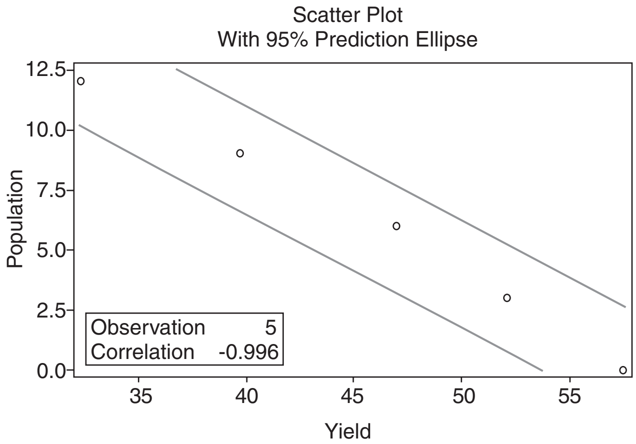

Fig 8 *Rumex spinosus* population vs grain yield

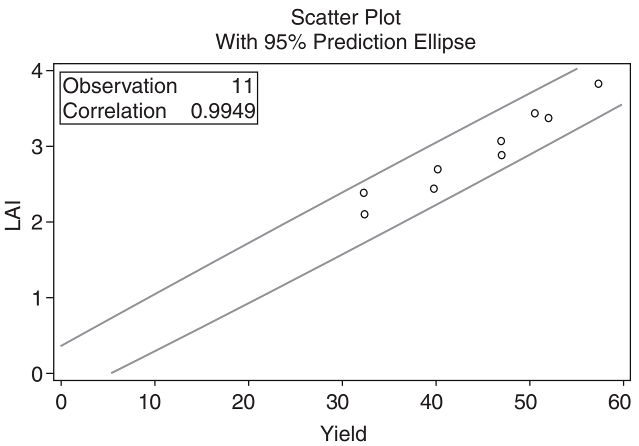

Fig 6 Grain yield and LAI

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