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EFFECT OF ROW ORIENTATION AND INTERCROPPING ON DRY MATTER ACCUMULATION AND GROWTH PARAMETERS OF BED PLANTED WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract- The field experiment was conducted on bed planted wheatat the research farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during rabi seasons of 2012-13 and 2013-14 in a split-plot design with four replications. The main plots treatments involved two orientation of sowing i.e. north-south and east-west. Each main plot was divided into five subplots to allocate the intercropping system with wheat, i.e. wheat+spinach, wheat+fenugreek, wheat+oats fodder, wheat+canola and wheat+ linseed along with sole crops. Raising the crop in east-west row orientation resulted in maximum dry matter accumulation, CGR, AGR and RGRas compared to north-south row orientation. Highest values of CGR and AGR were recorded between 60-90 DAS in wheat. Among the intercropping systems, performance of wheat under wheat + spinach and wheat + fenugreek intercropping systems was equivalent to sole wheat. In intercropping systems, canola was found to be more aggressive and competitive to wheat than the other crops.

Key words- AGR, CGR, dry matter accumulation, intercropping systems, PAR interception, row orientation, RGR, wheat

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Introduction

Wheat (*Triticum aestivum* L.), is a crop which triggered Indian green revolution. India has the largest area in the world under wheat. However, in terms of production, we are the second largest behind China only. Wheat occupies an important place as a food grain crop in Punjab's agriculture. It contributes about 20% of the total wheat production and about 13.0% of the wheat producing area of the country [1]. Raised beds were introduced in rice-wheat cropping system of the IGP in the mid 1990s. Since then, many advantages of growing wheat on beds have been reported, including increased yields, reduced lodging, opportunities for mechanical weeding, improved fertilizer placement, irrigation water savings, reduced water logging, reduced seed rate and opportunities for intercropping [2]. Permanent raised bed as a means of increasing the productivity and profitability of rice-wheat system. Bed planting has shown improved water distribution and efficiency, fertilizer use efficiency, reduced weed infestation, crop lodging and reduced seed rate without sacrificing yield [3]. Growth is a vital function of plants and indicates the gradual increase in number and size of cells. The processes of growth and development are considered to begin with germination, followed by large complex series of morphological and physiological events [4].Radiation and moisture are the basic meteorological parameters of significance to agriculture. Under potential conditions, with adequate moisture and fertility, radiation plays the role of a decisive factor for crop growth and development. Thus, manipulation of radiant energy within a crop field by an appropriate adoption of crop stands geometry, like row orientation and intercropping can provide a means to create light saturated condition for crop canopy for the purpose of efficient harvest of solar energy for agricultural production. An orientation of rows affects photosynthetic efficiency and canopy temperature as it affects interception of solar radiation by the crop canopy [5]. Intercropping is also known to intercept more solar energy and provide comparatively higher yield stability [6] and yield insurance during aberrant weather conditions compared with sole crops [7]. Advantages of intercropping in the crop production in comparison with pure cropping are due to the interaction between component crop stand and difference in competition for the use of environmental resources [8]. The productivity of intercropping system depends, to a large extent on the nature and extent of plant competition. In intercropping system the complementary effects between species are more likely due to spatial difference in canopy height and rooting pattern rather than temporal differences. Better light reception, air circulation and optimized phenological pattern in bed planting will increase the total assimilates available for spike growth, thereby increasing the potential for grain filling and permitting the maximum partitioning of the available assimilates to the spikes even though there was a reduction in spikes per unit area, the grains per spike and 1000 grain weight significantly increased and grain yield increased as a result of the integrative compensation between these yield components [9].In raised bed planted wheat, there is possibility of growing crops like spinach, fenugreek, oats fodder, canola and linseed in furrow. Increase in dry matter accumulation and physiological parameters can be achieved by effective row orientation and growing appropriate component intercrop with the principal crop.

Materials and methods

The experiment was carried out during *rabi* seasons of 2012-13 and 2013-14 at the research farm of the Department of Agronomy, Punjab Agricultural University, Ludhiana. Soil of the experimental field was loamy sand with pH 7.2. It was moderately fertile being low in organic carbon (0.21%), available nitrogen (63.5 kg/ha), available potassium (122.1 kg/ha) and medium in available phosphorus (19.5 kg/ha).The experiment was laid out in a split-plot design with two direction of sowing north-south and east-west in the main plot. Each main plot was divided into five sub plots to allocate the intercropping systems with wheat, i.e. wheat + spinach, wheat + fenugreek, wheat + oats fodder, wheat + canola and wheat + linseed. Wheat and intercrops were also sown in sole plots with four replications. Sowing of wheat on beds was done with the help of a bed planter, which enables two wheat rows 20 cm apart on 37.5 cm wide bed and makes 30 cm wide furrow between two beds and intercrops were sown in consecutive furrows. In sole plots, wheat and intercrops (spinach, fenugreek, oats fodder, canola and linseed) were sown at recommended row spacing. Sowing time for the wheat variety PBW 621 and intercrops was 7th November 2012 and 9th November 2013, respectively. The recommended dose of N, P and K fertilizer was applied to wheat and intercrops on area basis. The control of weeds on both beds and furrow was done by hand weeding. Other package of practices for wheat and intercrops were followed as per PAU recommendations. Wheat and intercrops were sown in 2:1 row arrangement. The advantage of intercropping systems and effect of row orientation between the components crops were evaluated using different physiological growth parameters.

Crop growth rate (CGR): It is the rate of growth per unit area and expressed as g/m^2/day.

$$\mathrm{CGR} = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{T2} - \mathrm{T1}} * \frac{1}{\mathrm{P}}$$

Where W_1 and W_2 are dry weights of plants at times T1 and T2 respectively and P is land area.

Relative growth rate (RGR): It indicates rate of growth per unit dry matter. It is expressed as g of dry matter produced by a g of existing dry matter in a day.

$$\mathrm{RGR} = \frac{\mathrm{loge\ W2} - \mathrm{logeW1}}{\mathrm{T2} - \mathrm{T1}}$$

Absolute growth rate (AGR): It indicates at what rate the crop is growing i.e. whether the crop is growing at a faster rate or slower rate than normal. It is expressed as g of dry matter produced per day.

$$\mathrm{AGR} = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{T2} - \mathrm{T1}}$$

Results and discussion

Effect on Dry Matter Accumulation

Crop growth analysis, one of the basic approaches to the analysis of yield influencing factors and plant development as net photosynthate accumulation is naturally integrated over time. Dry matter production and its accumulation are the best measures and index of the total performance and response of a crop [10]. Values from [Table-1] showed that there were no significant effects of row orientation and intercropping systems on dry matter accumulation at 30 DAS. At 60, 90, 120 DAS and at maturity dry matter accumulation was significantly higher in east-west row orientation as compared to north-south row orientation. Manipulating crop row orientation is a significant determinant of crop productivity and controlling weeds [11]. Crop rows oriented at east-west direction suppress weed growth through greater shading of weeds in the inter row spaces [12]. Regardless the positive role of row orientation in affecting weeds and crop yield, they have also a pivotal role in conserving soil water from evaporation. Values from [Table-1] showed that among the intercropping systems higher values of dry matter accumulation was found in wheat + spinach intercropping system which was statistically at par with wheat + fenugreek, wheat + oats fodder and wheat + linseed but significantly higher than wheat + canola intercropping system at 90, 120 DAS. At maturity, dry matter accumulation was significantly higher in wheat + spinach which were statistically at par with the wheat + fenugreek intercropping system but significantly higher than the rest of intercropping systems.

Table-1 *Dry matter accumulation (g/m^2) of bed planted wheat in relation to row orientation and intercropping systems (pooled data of two years)*

Treatment	Dry matter accumulation (g/m^2)				
	30 DAS	60 DAS	90 DAS	120 DAS	At maturity
Row orientation					
North-south (N-S)	33.5	299.7	708.5	939.2	1056.0
East-west (E-W)	34.5	325.1	760.1	1036.1	1199.6
CD (P=0.05)	NS	20.8	40.4	69.7	97.9
Intercropping system					
Wheat + spinach	35.0	317.1	751.0	1025.7	1199.6
Wheat + fenugreek	34.5	314.7	736.4	1005.1	1177.5
Wheat + oats fodder	33.6	311.3	727.3	977.8	1106.2
Wheat + canola	33.7	302.4	709.7	905.8	991.0
Wheat + linseed	33.1	308.7	717.9	964.1	1077.3
Sole Wheat	35.2	320.2	763.7	1047.4	1215.4
CD (P=0.05)	NS	NS	34.8	74.7	91.4

NS = Non- significant, DAS = Days after sowing

Effect on CGR and AGR

Crop growth rate (CGR), the gain in weight of a community of plants on a unit of land in a unit time. It is regarded as the most common representative of growth function because it represents the net results of photosynthesis, respiration and canopy area interaction. Crop growth rates (CGR) and absolute growth rate (AGR) are used extensively in growth analysis of field crops and these physiological parameters are best measure of the total performance of the crop [13]. Values from [Table-2,3] showed that CGR and AGR were lowest during time interval 0-30 DAS, which were gradually increased up to 60-90 DAS and after that declined. CGR and AGR were significantly higher in east-west row orientation as compared to north-south row orientation at all the periodic time interval except 0-30 DAS during both the growing seasons. No effect of intercropping systems was observed on CGR and AGR at 0-30 and 30-60 DAS. Among the intercropping systems, higher values of CGR and AGR were observed in wheat + spinach intercropping system at all the periodic time intervals which was statistically at par with the wheat + fenugreek, wheat +oats fodder but significantly higher than the wheat + linseed and wheat + canola intercropping system at 60-90 DAS. At 90-120 DAS and 120-maturity, CGR and AGR was significantly higher in wheat + spinach intercropping system which was statistically at par with the wheat + fenugreek intercropping system but significantly higher than wheat + oats fodder, wheat + linseed and wheat + canola intercropping system. Lowest values of dry matter accumulation, CGR and AGR were observed in wheat + canola intercropping system at all the periodic time intervals. It is because of canola is more aggressive, dominant and competitive to the wheat than rest of the intercrops, *viz.* spinach, fenugreek, oats fodder and linseed. All these intercrops possess different nature of growth, duration, plant habit, rooting pattern, canopy structure and days to maturity. Therefore, these crops differ in yield potential and possess differential competitive ability in intercropping systems.

Table-2 *Crop growth rate (g/m²/day) of bed planted wheat in relation to row orientation and intercropping systems (pooled data of two years)*

Treatment	Crop growth rate (g/m²/day)				
	0- 30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120- maturity DAS
Row orientation					
North-south (N-S)	1.12	8.87	13.63	7.69	3.89
East-west (E-W)	1.15	9.69	14.50	9.20	5.45
CD (P=0.05)	NS	0.48	0.55	0.55	0.53
Intercropping system					
Wheat + spinach	1.17	9.41	14.46	9.16	5.80
Wheat + fenugreek	1.15	9.34	14.06	8.96	5.75
Wheat + oats fodder	1.12	9.26	13.87	8.35	4.28
Wheat + canola	1.09	8.99	13.58	6.54	2.84
Wheat + linseed	1.10	9.18	13.64	8.21	3.77
Sole Wheat	1.17	9.50	14.79	9.46	5.81
CD (P=0.05)	NS	NS	0.75	0.65	0.60

NS = Non- significant, DAS = Days after sowing

Table-3 *Absolute growth rate (g/meter row length/day) of bed planted wheat in relation to row orientation and intercropping systems (pooled data of two years)*

Treatment	Absolute growth rate (g/meter row length/day)				
	0- 30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120- maturity DAS
Row orientation					
North-south (N-S)	0.38	3.00	4.60	2.59	1.31
East-west (E-W)	0.39	3.27	4.91	3.10	1.84
CD (P=0.05)	NS	0.19	0.22	0.20	0.09
Intercropping system					
Wheat + spinach	0.39	3.17	4.89	3.09	1.96
Wheat + fenugreek	0.39	3.15	4.76	3.02	1.94
Wheat + oats fodder	0.38	3.12	4.69	2.82	1.44
Wheat + canola	0.37	3.04	4.60	2.21	0.96
Wheat + linseed	0.38	3.10	4.62	2.77	1.27
Sole Wheat	0.40	3.21	4.99	3.19	1.96
CD (P=0.05)	NS	NS	0.23	0.25	0.13

NS = Non-significant, DAS = Days after sowing

Effect on RGR

RGR in wheat was initially high and decreased with time and much of this decline attributed to an increase of self shading among canopy leaves [14]. There were no significant effects of row orientation and intercropping systems on RGR of wheat at 30-60 and 60-90 DAS. At 90-120 DAS and 120-maturity, RGR was significantly higher in east-west row orientation than the north-south row orientation [Table-4]. Among the intercropping systems, wheat + canola intercropping system resulted significantly lower value of the RGR of wheat at 90-120 DAS and 120-maturity periodic time interval than the rest of intercropping systems [Table-4]. By comparing the sole wheat with intercropping systems, it was found that dry matter accumulation, CGR, AGR and RGR (at 120-maturity) in sole wheat was statistically at par with wheat + spinach and wheat + fenugreek intercropping systems but significantly higher than the other intercropping systems. It was due to the less competitive ability of spinach and fenugreek to the wheat as compared to the canola, oats fodder and linseed in intercropping system.

Yield

There was significant effect of row orientation and intercropping systems on grain yield of wheat. Grain yield (55.1 q/ha) was significantly higher in east-west row orientation as compared to grain yield (48.1 q/ha) in north-south row orientation (Mean of two years data) [Fig.-1]. Among the intercropping systems higher grain yield of wheat was found in wheat + spinach (54.9 q/ha) intercropping system which was statistically at par with wheat + fenugreek (53.7 q/ha) and wheat + oats fodder (51.5 q/ha) but significantly higher than wheat + linseed (50.8 q/ha) and wheat + canola (43.3 q/ha) intercropping system [Fig.-2]. Significantly lowest value grain yield were observed in wheat + canola intercropping system than the rest of the intercropping systems. It is because of canola is more aggressive, dominant and competitive to the wheat than the other intercrops and it was more exposed to the sun, so wheat suffered more as it was growing under the canola canopy.

Table-4 *Relative growth rate (g/g/day) of bed planted wheat in relation to row orientation and intercropping systems (pooled data of two years)*

Treatment	Relative growth rate (g/g/day)			
	30-60 DAS	60-90 DAS	90-120 DAS	120- maturity DAS
Row orientation				
North-south (N-S)	0.073	0.029	0.009	0.003
East-west (E-W)	0.075	0.029	0.010	0.004
CD (P=0.05)	NS	NS	0.0005	0.0005
Intercropping system				
Wheat + spinach	0.075	0.029	0.010	0.005
Wheat + fenugreek	0.075	0.029	0.010	0.005
Wheat + oats fodder	0.074	0.028	0.010	0.004
Wheat + canola	0.074	0.028	0.008	0.003
Wheat + linseed	0.074	0.028	0.010	0.004
Sole Wheat	0.075	0.029	0.010	0.005
CD (P=0.05)	NS	NS	0.001	0.0006

NS = Non-significant, DAS = Days after sowing

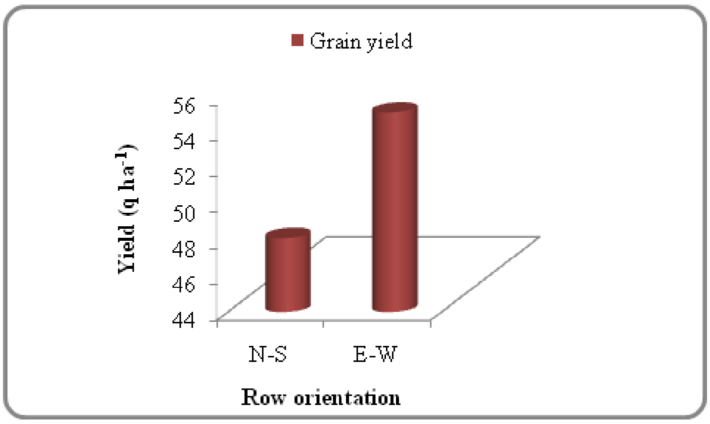

Fig-1 Effect of row orientation on wheat yield

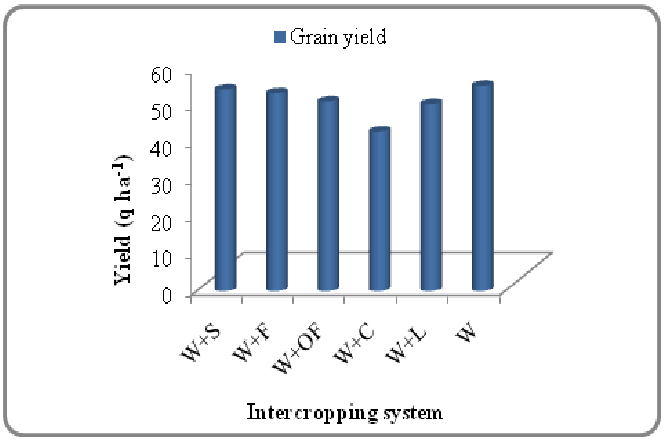

Fig-2 Effect of intercrops on wheat yield

Conclusion

From the study, it was concluded that there were advantage in dry matter accumulation, growth parameters and yield by raising the crop in east-west row orientation as compared to north-south row orientation. Among the intercropping systems, performance of wheat + spinach and wheat + fenugreek intercropping systems was equivalent to sole wheat. Whereas, canola was found to be more aggressive and competitive to wheat than the other component crops in intercropping system.

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