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Assessments of the Relationship between Effective leaf area, Yield Components and Protein Content in Wheat (*Triticum aestivum* L.) under Water Stress Conditions at Eastern Sudan

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Abstract: A field experiment was conducted during 2010/2011 and 2011/2012 seasons to estimate the relationship (at $P \leq 0.05$ or $P \leq 0.01$) between effective leaf area index LAI, yield attributing characters and protein content in wheat as affected by water stress, nitrogen and organic manure. Positive significant correlations between plant height, LAI and shoot biomass with number and weight of grains plant^{-1} and grain yield were found in both seasons. The correlation coefficient values between these traits were more than 0.80. The results of regression analysis indicated that linear model gave the best fit for regression of grain weight plant^{-1} and LAI for grain yield in both seasons. The higher determination coefficients (R^2 =0.87 and 0.88) indicating that more than 87% of total variations of grain yield can be attributed to variation of grain weight per plant, LAI, number of grains spike^{-1}, harvest index and plant height of the analyzed wheat crop. These results suggest that LAI (until anthesis phase of development) could be used in agricultural models for biomass estimation useful in yield prediction. The significant positive correlations between grain protein content and grain weight per plant, LAI, shoot biomass and spike length indicated their unlimited contribution to total grain yield and protein content.
Keywords: wheat, organic manure, yield, water stress, correlation, regression

INTRODUCTION

Although, Sudan is considered as a marginal area of wheat production, the wheat crop ranks second after sorghum and now has become a strategic crop due to the shortage of food in the world and to the drastic change in the consumption habit of the people in Sudan [1, 2]. Wheat is a main crop that provides protein and carbohydrates for many people [3]. Numerous researchers have studied relations between yield and different yield components [4, 5]. They noticed positive correlation between number of productive tillers, aerial biomass and leaf area index (LAI) at flowering stage with irrigation frequency. The mean and range for leaf area index (one of the most important biophysical index involved in several canopy functioning processes [6]. Many authors [7, 8] observed positive correlation between grain yield and yield components like number of effective tillers, fertile spikelets and grains per spike which were increased due to increase in irrigation frequencies. Zorita [9] obtained a strong correlation between wheat grain yield and N fertilization. Grain yield per plant was positively and significantly correlated with number of tillers per plant and spikelets per spike. Many authors [10, 11, 12] reported that the progress in grain yield of wheat in Sudan was accompanied with the increase in harvest index, grains per spike, and grain filling duration.

The objective of this investigation was to establish the relationship among the total grain yield, effective growth traits and yield components as well as grain protein content in wheat (*Triticum aestivum* L).

MATERIALS AND METHODS

Tow field experiments were carried out during successive seasons 2010/011 and 2011/012 at Demonstration Farm of the Faculty of Agriculture and Natural Resources, University of Kassala at New Halfa, Eastern Sudan (Latitude 15° 19´ N. Longitude 35° 36´E and Altitude 45 m asl). The experiment laid out in strip-split plot design in three replications. There were three watering intervals (W1, W2, W3) irrigation every (7, 14 and 21 days), three levels of nitrogen (0, 43 and 86 kg N/ha) with or without organic fertilizer (chicken manure) at rate of 4 ton ha^{-1}. Chicken manure treatments were assigned to the main plots, irrigation and nitrogen levels treatments were allocated in the 1rst and 2nd order subplots, respectively. Nebta wheat cultivar was sown in the second week of November in each season. All cultural practices of wheat were applied properly as recommended for the region. At flowering stage, data of plant height, biomass per plant and leaf area index (LAI) were recorded using standard procedures. Leaf area per plant was computed by length and breadth method by followed procedure given by [13] as following:-

Leaf area(LA) of each leaf in middle tiller = L × W × K

L: maximum length of leaf (cm),W : maximum width of leaf (cm)
K: Adjustment factor (0.8). And leaf area index was calculated using the following formula:-

$$LAI = \frac{\text{LA (cm}^2}{\text{Land area } \left(\text{cm}^2\right)}$$

Ten plants from each sub-plot were collected to determine shoot biomass plant^{-1} weight (g). The plant was oven dried 70 – 80 C° to a constant weight using a sensitive balance.

At harvesting, spikes were collected from two square meters area of each sub-subplot. After open air drying, grains were threshed from the straw, cleaned and weighing. Then grain yield per hectare was then calculated. Also. The grains were ground to a fine powder and protein content for grain estimated by improved Kjeldahl- method and crude protein percentage was calculated by multiplying the total nitrogen in grain by 5.7.

Harvest index (HI) was calculated as the ratio of gain yield to the total above ground shoot biomass as follows:

HI = (Grain yield)/ (Biological yield) x 100

All collected data of aforementioned characters were used for correlation and regression analysis.

Correlation and regression studies

Correlation analysis using Pearson's simple correlation coefficients and multiple regressions (stepwise) was used to determine the interdependence of the traits and study the nature and degree of relationship between total grain yield, effective growth traits and yield components in wheat. Statistical calculations were done using the SPSS program version 16.

RESULTS AND DISCUSSION

Data in table (1) presented correlation analysis between some growth, heading date, yield attributes and grain protein content in 2010/011 (below) and 2011/012 (above) seasons.

Generally, in the both years of investigation. The correlation coefficient values were highest between grain yield and the most characters studied. In this respect, there was significant positive correlation of heading date with plant height, LAI, shoot biomass, yield and yield attributes in both seasons and with grains yield per plant and grain protein content in second season only. The results indicated that late headed plants produced higher magnitude of mean value of these characters. The significant positive correlation of heading date with plant height indicated that lateness was associated with tallness of wheat plants, this finding supported by those reported by Sultan *et al.;* [14]. In this study, plant height showed highly significant positive correlation with LAI, shoot biomass, yield attributes in both seasons, indicating that taller plants performed better for these characters. However, Pyruvic [15] and [16] concluded that plant height, number and weight of grains per plant, spikelets per spike and grain yield per hectare were highly positive correlated. This could explain the positive correlation of plant height with yield attributes found in this investigation. Further, the significant positive correlation of both shoot biomass and LAI with all characters was observed in both seasons. Increasing LAI is one of the ways for increasing the capture of solar radiation within the canopy and production of dry matter, hence dry matter production increased with an increase in LAI. Moreover, positive correlation of LAI with yield and yield components might be due to positive relationship between shoot biomass and LAI discussed later. Petcu *et al.;* [17] found positive correlation between LAI and number of grains in wheat plants.

In this study, the significant positive correlation of biomass with number and yield of grains per plant in both seasons, were indicating that an increase in biomass could also increase number and yield of grains per plant and consequently increase grain yield. Supporting evidences were reported by Singh [18] who observed a positive correlation between dry matter, number and weight of grains per plant. Also, the result showed significant positive correlation of grain yield ha^{-1} with yield attributed characters in both seasons and with grain protein content in the second season only.

These results were approximately accordance with those found by many researchers [7, 14, 17, 18, 19, 20]. The positive correlation indicated the contribution of yield attributing characters and grain protein content to the grain yield production. In this regard, Blanco *et al.;* [20] reported that grain protein content had high positive correlation with grain yield. It is not surprising that HI is associated with yield increases, so in this investigation there was significant positive correlation of HI with spike length, grain yield, number of grains and yield per plant. These results have been reported by many researchers [12, 21, 22, 23]. The significant positive correlation of spike length with all yield attributes in both seasons except HI and grain protein content in second season, could be suggested that the longer the spike length would be the higher the number of spike lets spike^{-1}, number of grains per spike, grains yield per plant and as a result increased in other yield attributes. This result is in conformity with those findings reported by [14, 24]. The results showed significant positive correlation of spikelets spike^{-1} with other yield attributes in both seasons. These results indicated that higher number of spikelets per spike would be companied by higher mean values of these characters. Similar results were obtained by Petcu *et al.;* [17] who reported the significant positive correlation of spikelets spike^{-1} with spike length, number of grains per spike and grains yield per plant. While Sultana *et al.;* [14] concluded that spikelets per spike significantly had positive correlation with spike length, number of grains per spike, tillers, biomass and grains yield per unit area. The number of grains per spike was significantly correlated with the most characters of yield and related traits in both seasons. White and Wilson [22] found positive correlation between number of grains per spike, HI and grains yield. In this respect, Gorjanovic and Marija [24] reported that the number of grains per spike had significant positive correlation with HI and grain weight per spike. In this study, grains yield per plant had significant positive correlation with all yield components in both seasons and with grain protein content in the second season only. These results indicated the contribution of yield per plant to all attributing characters and grain protein content. These findings could be partially accordance with those found by those workers [11, 14, 17, 24]. The positive correlations between grain protein content and grain weight per plant, LAI, shoot biomass and spike length indicated their unlimited contribution to total grain protein content. Further, the significant positive correlation of grain protein content with grain yield obtained in this study in the second season was agreed with those findings reported by Upadhay *et al.;* [21] who concluded that grain protein content had positive correlation with grain yield.

Based on experimental results, stepwise regression analysis showed significant and complex relationship between analyzed characters table (2). The results of regression analysis indicated that the linear polynomial models gave the best fit for regression of grain weight per plant and LAI on total grain yield in both seasons. In the second season best fit for regression model could be the last one in the table (2). The higher determination coefficients R^2 the best model. The magnitude of determination coefficient of grain weight per plant and LAI on total grain yield (R^2 =0.87) in first season indicating that approximately 87% of total variations of grain yield can be attributed to variation of grain weight per plant and LAI. While determination coefficient of the best model (R^2 =0.88) indicating that approximately 88% of total variations of grain yield can be attributed to variation of grain weight per plant, LAI, number of grains spike^{-1}, harvest index and plant height. Similar result was observed by [17]. The coefficients of determination (R^2= 0.87) between harvest index and grain yield was closely similar to that (R^2=0.86) between leaf area index and grain yield. This means that wheat crops with the highest harvest index necessarily have the highest leaf area.

According to results of this study, grain yield increased with increasing of LAI per plant (until an thesis) linearly. These results showed that LAI and grain yield per plant has greater contribution to grain yield and yield attributing characters.

Table-1: Correlation coefficient between means of LAI, yield and yield attributes characters of wheat plant as affected by water stress, organic manure with or without nitrogen fertilization during 2010/011 (below) and 2011/012 (above) seasons.

Means means	Grains yield /plant	Spike length	No.of spikelet /spike	No.grains /spike	Grain yield kg/ha	HI	Grain protein content	Plant height	Shoot biomass	LAI	Heading date
Grains yield/plant		0.7**	0.7**	0.8**	0.9**	0.6**	0.3*	0.8**	0.9**	0.7**	0.6**
Spike length	0.7**		0.8**	0.7**	0.8**	0.5**	0.4**	0.6**	0.7**	0.7**	0.6**
spikelets/spike	0.8**	0.9**		0.6**	0.8**	0.5**	0.2^{NS}	0.6**	0.7**	0.7**	0.6**
grains /spike	0.9**	0.8**	0.8**		0.9**	0.6**	0.1^{NS}	0.6**	0.7**	0.6**	0.5**
Grains yield/ha	0.9**	0.7**	0.8**	0.9**		0.7**	0.4**	0.8**	0.8**	0.8**	0.6**
HI	0.6**	0.3^{NS}	0.5**	0.6**	0.6**		0.3**	0.5**	0.6**	0.6**	0.4**
Grain protein content	0.2^{NS}	0.2^{NS}	0.1^{NS}	0.2^{NS}	0.2^{NS}	0.2^{NS}		0.2^{NS}	0.5**	0.4**	0.1^{NS}
Plant height	0.8**	0.7**	0.7**	0.8**	0.8**	0.5**	0.2^{NS}		0.7**	0.7**	0.5**
Shoot biomass	0.8**	0.8**	0.8**	0.8**	0.8**	0.6**	0.4**	0.7**		0.7**	0.6**
LAI	0.8**	0.8**	0.8**	0.9**	0.9**	0.6**	0.4**	0.8**	0.8**		0.9**
Heading date	0.02 ^{NS}	0.6**	0.6**	0.6**	0.7**	0.4**	0.2^{NS}	0.7**	0.7**	0.8**	

**: Correlation is significant at the 0.01 level (2-tailed).
*: Correlation is significant at the 0.05 level (2-tailed).
$_{NS}$: Correlation is none significant at the 0.05 level (2-tailed).

Table-2: Relationships between the investigated agronomic variables

season	Dependent variable (Y)	Independent Variable(s)	Regression models	Determination coefficients R^2
2010/011	Yield	1-Grains weight /plant=X_1	Y = 1031.25 +827.73X1	0.84
		2- LAI= X_2	$Y = 858.05 + 520X_1 + 115.5 X_2$	0.87
2011/012		1-Grains weight /plant=X_1	$Y = 1375.13 + 681.5 X_1$	0.77
		2- LAI= X_2	$Y = 301.9 + 493.5 X_1 + 223.1 X_2$	0.83
		3-number grains/spike=X_3	$Y = -234.6 + 349.1 X_1 + 213.8 X_2 + 22.7 X_3$	0.85
		4- Harvest index= X_4	$Y = -1051.8 + 319.1 X_1 + 180.3 X_2 + 19.9X_3 + 32.3 X_4$	0.86
		5-plant height = X_5	$Y = -1765.7 + 258.2 X_1 + 144.3 X_2 + 17.9X_3 + 30.9 X_4 + 24.8 X_5$	0.88

CONCLUSION:

From the obtained results it is worthy to suggest that LAI (until a thesis phase of development) could be used in agricultural models for grain yield per plant estimation useful in yield prediction.

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