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Shoot Growth Curve Analysis of Wheat (*Triticum aestivum* L.) Receiving Different Levels of Boron and Iron

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Abstract: The effect of boron and iron was studied on wheat subjected to moisture stress. All possible combinations of 0, 2, and 4kg ha^{-1} of B and 0, 10 and 20kg ha^{-1} of Fe were studied in the experiment on Barani-70 variety of wheat which was subjected to early stress by delaying the first irrigation to 20 days after sowing instead of 10 to 15 days after sowing. Logistic function was fitted to shoot mass recorded at 15 days interval and useful biological constants were calculated. Logistic function fitted the data well. B @ 2kg ha^{-1} and Fe @ 10kg ha^{-1} and their combination increased AGR and the maximum biomass but their combination at the highest levels decreased the maximum biomass. RGR maximum which occur at initial stage of the crop growth was only increased by iron application @ 20kg ha^{-1} and by combination of B and Fe at their highest levels.

Key words: Boron, growth curve, iron, root mass, shoot mass, wheat

Introduction

Micronutrient deficiencies are attributed to removal by high yield crop varieties, intensive systems of cultivation, indiscriminate and consistent use of chemical fertilizers and reduced use of organic manures of the factors which create imbalances in the availability of micronutrient. However, intensively cropped areas are becoming deficient in micronutrient especially in areas where practically every plant part except roots are removed as in major crop production areas of NWFP. Moreover, results of the research studies in NWFP revealed that there were some areas where one or more micronutrient are required for normal crop production (Khattak *et al.*, 1983). The soil of the crop experimental area of the Malkandher Farm of the NWFP Agricultural University, Peshawar was analyzed and found to be deficient in boron and iron in addition to nitrogen, phosphorus and organic matter. Boron and iron are the two of 17 essential elements, required for proper growth and higher yields of crop plants. Water shortage is another most widely distributed constraint to crop production. Therefore, an experiment was thus designed to study the effect of boron and iron application on growth of wheat subjected to early moisture stress by withholding the first irrigation and to analyze growth curves of shoot mass.

Materials and Methods

The experiment was conducted during 1998-99. The soil of the experimental farm is silty clay loam in nature, low in organic matter, nitrogen, phosphorus, boron and iron, shallow, well drained and alkaline in reaction with a pH of 7.9. All possible combinations of three levels of B (0, 2 and 4kg ha^{-1}) and three levels of Fe (0, 10 and 20kg ha^{-1}) were studied in the experiment. Borax and ferrous sulphate were used to supply B and Fe, respectively. The experiment was conducted using a randomized complete block design (Steel and Torrie, 1990). A plot size of $3x5m^2$, having 10 rows 30cm apart and 5 m long, was used. Barani-70 variety of wheat, recommended for rainfed areas was used. The experiment was subjected to early moisture stress by delaying the first irrigation by about one month instead of 10 to 15 days after emergence. Wheat plants were sampled at 15 days interval and were separated into roots and shoots. The plants were dried in oven and were weighed to record shoot weight.

From a theoretical mathematical approach polynomials are quite inappropriate for quantitative analysis of plant growth; they are used to obtain good fit but the parameters of the polynomials have no biological relevance (Richards, 1959). Total mass of plants or plant parts become asymptotic with time and based on the theoretical consideration. Nonlinear growth functions are the most appropriate for describing changes in weight with time because the growth functions account for the form of growth curves through certain fundamental postulates about the growth processes (Richards, 1969). Moreover, useful biological constants can be derived from parameters of the specialized growth functions. Monomolecular, Logistic, Gompertz, Richards, and other functions have been used to describe plant growth curves. Thus, in order to analyze the growth curves and derive useful physiological parameters for comparison of the treatments, Logistic function was fitted to the data in the form of Richards function with parameter N equal to minus one because many useful things can be calculated from the Richards function and thus from Logistic function in the form of Richards function.

Logistic function: $Y = K/[1+Exp(A-CX)]$
Richards function: $Y = K[1 \pm Exp(A-CX)]^{\wedge}(1/N)$

where
Y is observed growth data
K is the maximum biomass
A is the intercept
C is the rate parameter,
N is parameter that vary with point of inflection
X is time in days after emergence

Logistic function is a symmetrical function bounded by two asymptotes, $K/[1+exp(A)]$ and K at time zero and infinity. For crop growth the lower asymptote is seedling weight at emergence and the upper asymptote is final total crop weight at physiological maturity. C is a rate constant where higher values show a rapid rise of the function between the two asymptotes. The estimates of all three parameters are correlated with each other. As it is a symmetrical function, the point of inflection occurs when 50% of the total biomass has been accumulated. The following linear form of the Richards function was used for fitting to the data by interaction using "what-if" capability of Lotus 1-2-3 spreadsheet program. Rather a worksheet was programmed to calculate the parameters and the useful parameters and it worked nicely.

$Ln[(Y/K)^{\wedge}N-1] = A-CX$

Coefficient of determination or r^2 were calculated, r^2 (T) is coefficient of determination based on linear form of the function, r^2 is coefficient of determination based on original values.

$r^2(T)$ = Regression SS/(Regression SS + Residual SS)
r^2 = (Sum of cross product)/{(SS X)*(SSYhat)

Table 1: **Effect of boron and iron on parameters of logistic function and derived physiological characteristics of shoot growth curve of wheat. Application of B @ 2 kg ha^{-1} and Fe @ 10kg ha^{-1} increases the K or the maximum biomass.**

Parameters	Control	Fe1	Fe2	B1	B2	Fe1B1	Fe1B2	Fe2B1	Fe2B2
K	165.0	233.0	170.0	219.0	177.0	264.0	232.0	187.0	158.0
A	7.601	8.387	7.985	7.441	7.818	8.879	7.544	8.082	8.412
C	0.092	0.089	0.093	0.080	0.089	0.089	0.079	0.091	0.110
r^2(T)	0.983	0.990	0.989	0.987	0.988	0.993	0.991	0.992	0.975
r^2	0.966	0.968	0.986	0.965	0.976	0.984	0.990	0.987	0.963
AGR Max.	3.808	5.210	3.938	4.363	3.944	5.901	4.581	4.259	4.363
RGR Max.	0.092	0.089	0.093	0.080	0.089	0.089	0.079	0.091	0.110
AGR Wted.	2.538	3.473	2.625	2.909	2.630	3.934	3.054	2.839	2.909
RGR Mean	0.046	0.045	0.046	0.040	0.045	0.045	0.039	0.046	0.055
Y at POI	82.3	93.8	86.2	93.4	87.7	99.3	95.5	88.7	76.1
Reg Var	10642	14793	9704	12074	10330	17882	13452	11028	1404
Res Var	284	371	102	332	188	219	106	111	329

B1 is 2kg B ha^{-1}, B2 is 4kg B ha^{-1} Fe1 is 10kg Fe ha^{-1}, Fe2 is 20kg Fe ha^{-1}, K is the maximum biomass, A is the intercept, C is the rate parameter, r^2(T) is coefficient of determination based on linear form of the function, r^2 is coefficient of determination based on original values, AGR Max. is maximum absolute growth rate or AGR at POI, RGR Max. is maximum Relative growth rate or AGR Wted. is weighted absolute growth rate, RGR mean is mean relative growth rate POI is point of inflection, Y at POI is dry matter at POI, Reg Var is regression variance, Reg Var is regression variance and Res Var is residual variance.

The following useful biological constants were derived from the parameters

Maximum AGR i.e. AGR at POI = K(-B){(1-N)^[(1-N)/N]}
Theoretical maximum RGR = B/N
Weighted mean AGR = K(-B)/[2(1-N)+2]
Weighted mean RGR or RGR at POI = (-B)/(1-N)
Y at POI = K(1-N)^1/N
Absolute growth rate (AGR) at any X= {-BY[(K/Y)^N-1]}/N
RGR at any X= {(-B)[(K/Y)^N-1]}/N

Results and Discussion

Parameters of the logistic function and useful physiological constants of the are given in Table 1. Use of logistic function gave very good fit with coefficient of determination ranging from 0.975 to 0.992 based on the transformed data fitted in linear form and 0.9629 to 0.9896 based on the original data. Boron application @ 2kg ha^{-1} and Fe application @ 10kg ha^{-1} increased the K value which means they increase the maximum biomass or asymptote of the biomass curve. Combination of 2kg ha^{-1} B and 10kg ha^{-1} Fe increased the K value but combination of the highest values of B and Fe decrease K. Boron and Fe application increased AGR maximum which occurred at the point of inflection of the biomass curve; the two micro nutrients @ 2 and 10kg ha^{-1} respectively increased the maximum AGR. These results are in line with an early work of Shah (1988). Combination of 2kg ha^{-1} B and 10kg ha^{-1} Fe increased AGR maximum more than any other treatment. RGR maximum which occurred at initial stage of the crop growth was only increased by iron application @ 20kg ha^{-1} and by combination of B and Fe at their highest levels. Weighted mean AGR was also increased by the application of the two micronutrient. Using parameters of the growth function curves of the dry matter accumulation in shoot and the corresponding AGR curves were obtained for different levels of B and Fe (Table 1). Nice fitting and curves were obtained which depict properties of the physiological constants described above.

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