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A suggested statistical approach for dealing with the non-significant interactions between treatments

Zakaria Mohamed Sawan

Cotton Research Institute, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Giza, Egypt; zmsawan@hotmail.com

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ABSTRACT

A field experiment was conducted to study the effect of nitrogen (N) fertilizer and foliar application of potassium (K) and Mepiquat Chloride (MC) on yield of cotton. Seed cotton yield per plant and seed cotton and lint yield per hectare; have been increased due to the higher N rate and use of foliar application of K and MC. No significant interactions were found among the variables in the present study (N, K and MC) with respect to characters under investigation. Generally, interactions indicated that, the favorable effects ascribed to the application of N; spraying cotton plants with K combined with MC on cotton productivity, were more obvious by applying N at 143 kg per hectare, and combined with spraying cotton plants with K at 957 g per hectare and also with MC at 48 + 24 g active ingredient per hectare. Sensible increases were found in seed cotton yield per hectare (about 40%) as a result of applying the same combination. However, this interaction did not reach the level of significance, so, statistical approach for dealing with the non-significant interactions between treatments, depending on the Least Significant Difference values has been suggested, to provide an opportunity to disclosure of the interaction effects regardless of their insignificance. As a matter of fact the original formula used in calculating the significance of interactions suffers a possible shortage, which can be eliminated through applying the new suggested formula.

Keywords: Cotton Yield; Mepiquat Chloride; Nitrogen; Non-Significant Interactions; Potassium

1. INTRODUCTION

Managing the balance of vegetative and reproductive growth is the essence of managing a cotton crop. It is well known from numerous fertilizer experiments that the yield of field crop has been dependent strongly on the supply of mineral nutrients [1-3]. Excess of vegetative growth, poor bud development, shedding of fruiting forms, and growth imbalance between the source and sink are responsible for the unpredictable behavior of the crop. Several approaches have tried-out to break this yield plateau, among them the application of plant growth regulators (PGR's), particularly Mepiquat Chloride (MC) that has received greater attention recent years [4,5].

The objective of this study was to evaluate the effects of N fertilization rate, foliar K application, and MC application on the yield of cotton with the aim to identify production treatments that may improve the yield. Also, we suggested a statistical approach for dealing with the non-significant interactions between treatments depending on the Least Significant Difference values, regardless of statistical insignificance.

2. MATERIALS AND METHODS

A Field experiment was conducted at the Agricultural Research Center, Ministry of Agriculture in Giza (30˚N, 31˚28'E and 19 m altitude), Egypt using the cotton cultivar "Giza 86" (Gossypium barbadense L.) in I and II seasons. The soil texture in both seasons was a clay loam, with an alluvial substratum, (pH = 8.10, 44.75% clay, 27.40% silt, 20.00% fine sand, 3.00% coarse sand, 2.85% calcium carbonate and 1.85% organic matter). Each experiment included 16 treatment combinations of: 1) two N rates (95 and 143 kg N per hectare), which were applied as ammonium nitrate (NH_4NO_3, 33.5% N) at two equal doses, 6 and 8 weeks after planting. Each application (in the form of pinches beside each hill) was followed immediately by irrigation. 2) four K rates (0, 319, 638 and 957 g K per hectare) were applied as potassium sulfate (K_2SO_4, "40% K") as a foliar spray, 70 and 95 days after planting (during square initiation and boll development stage). The solution volume applied was 960 L per hectare. 3) two rates from the PGR, 1,1-dimethylpiperidinium chloride (Mepiquat Chloride "MC" or "Pix") were foliar applied (75 days after planting at 0 or 48 g active ingredient per hectare, 90 days after planting at 0 and 24 g active ingredient per hectare) where the solution volume applied was also 960 L per hectare. The K and MC were applied to the leaves with uniform coverage using a knapsack sprayer. The pressure used was 0.4 kg per cm^2, resulting in a nozzle output of 1.43 L per min. The application was carried out between 9.0 and 11.0 h.

A randomized complete block design with four replications was used for both experiments. Seeds were planted on 3 April, in season I and 20 April, in season II. Plot size was 1.95 × 4 m including three ridges (beds) (after the precaution of border effect was taken into consideration). Hills were spaced 25 cm apart on one side of the ridge, with seedlings thinned to two plants $hill^{-1}$ six weeks after planting. This provided a plant density of 123 000 plants per hectare. The total amount of irrigation applied during the growing season (surface irrigation) was about 6 000-m^3 per hectare. The first irrigation was applied three weeks after planting, with the second three weeks later. Thereafter, plots were irrigated every two weeks until the end of the season (October 11, in season I and October 17, in season II, respectively), for a total of nine irrigations. On the basis of soil test results, phosphorus (P) fertilizer was applied at the rate of 24 kg P per hectare as calcium super phosphate during land preparation. The K fertilizer was applied at the rate of 47 kg K per hectare as potassium sulfate before the first irrigation (the recommended level for semi-fertile soil). Fertilization (P and K), along with pest and weed management was carried out during the growing season, according to the local practice performed at the experimental station.

In both seasons, ten plants were randomly taken from the center ridge of each plot to determine the seed cotton yield in g per plant. First hand picking was made on 20 and 26 September and final picking on 11 and 17 October in season I, and season II, respectively. Total seed cotton yield of each plot (including ten plant sub samples) was ginned to determine seed cotton and lint yield (kg per hectare).

Results were analyzed as a factorial experiment in a randomized complete block design for the studied characters each season and the combined statistical analysis for the two seasons, following the procedure outlined by Snedecor and Cochran [6]. The Least Significant Difference (L.S.D.) test method, at 5% level of significance was used to verify the significance of differences among treatment means and the interactions to determine the optimum combination of N, K and MC.

3. RESULTS AND DISCUSSION

Results from the analysis of variance for yield (combined data of the two seasons) are presented in **Table 1**.

3.1. Effects of Main Treatments on Yield

Seed cotton yield per plant, as well as seed cotton and lint yield per hectare, were increased by as much as 12.8, 12.8, and 12.3%, respectively, when the nitrogen rate was increased (**Table 2**). There were both increased boll numbers and boll weight, which was attributed to the fact that N is an important nutrient for control of new growth and preventing abscission of squares and bolls and is also essential for photosynthetic activity [7,8]. When K was applied at all three K rates (319, 638 and 957 g K per hectare), seed cotton yield $plant^{-1}$ and seed cotton and lint yield ha^{-1} were also increased. These increases could be attributed to the favorable effects of K on yield components, *i.e.* number of opened bolls per plant, and boll weight, leading consequently to higher cotton yield [9,10]. Mepiquat Chloride, significantly increased seed cotton yield per plant, as well as seed cotton and lint yield per hectare (by 9.5, 9.6, and 9.3%, respectively), compared to the untreated control. These results may be attributed to the promoting effect of this substance that has beneficial and supplemental affects leading to yield enhancement (boll retention and boll weight) [11].

3.2. Effects of Interactions between Treatments on Yield

No significant interactions were found among the variables in the present study (N rates, K rates and MC) with respect to the characters under investigation. Generally, interactions indicated that, the favorable effects accompanied the application of N; spraying cotton plants with K combined with MC on cotton productivity, was more obvious by applying N at 143 kg per hectare, and combined with spraying cotton plants with K at 957 g per hectare and also with MC at 48 + 24 g active ingredient per hectare. Regarding the non-significant interaction effects, sensible increases were found in seed cotton yield per hectare (about 40%) as a result of applying the same combination.

In this experiment there are sensible differences between the interactions, *i.e.* the first order (**Tables 3-5**), and the second order (**Table 6**). However, these interactions did not reach the level of significance, so, suggested statistical approach for dealing with the non-significant interactions between treatments, depending on the Least Significant Difference values to verify the sig-

Table 1. Mean squares for combined analysis of variance for yield in cotton during season I and season II.

Source	d.f.	Seed cotton yield (g per plant)	Seed cotton yield (kg per hectare)	Lint yield (kg per hectare)
Year	1	147.21**	1 415 571.4**	332 917.8**
Replicates within years	6	40.27*	404 859.0*	50 458.4*
Treatments	15	75.94**	714 189.8**	83 868.9**
Nitrogen (N)	1	456.74**	4 325 402.3**	500 162.5**
Potassium (K)	3	132.53**	1 223 590.9**	145 491.8**
Mepiquat Chloride (MC)	1	261.15**	2 504 937.5**	294 768.0**
N × K	3	3.47	31 778.5	3 934.8
N × MC	1	0.17	1 463.4	298.6
K × MC	3	4.19	36 432.4	4 632.6
N × K × MC	3	0.18	1 879.3	209.1
Treatments × Year	15	2.50	24 239.8	3 070.9
Error	90	14.36	135 377.4	16 752.8
SD		3.79	367.9	129.4
CV%		12.04	12.0	12.0

*Significant at P = 0.05; **Significant at P = 0.01.

Table 2. Effect of N-rate and foliar application of K and MC on yield in cotton combined over two seasons I and II.

Treatment	Seed cotton yield (g per plant)	Seed cotton yield (kg per hectare)	Lint yield (kg per hectare)
N rate (kg per hectare)			
95	29.58[b]	2882.3[b]	1020.0[b]
143	33.36[a]	3250.0[a]	1145.0[a]
LSD (0.05)	1.33	128.9	45.4
K rate (g per hectare)			
0	28.61[b]	2792.5[b]	988.2[b]
319	31.51[a]	3068.6[a]	1083.4[a]
638	32.51[a]	3163.0[a]	1115.2[a]
957	33.25[a]	3240.7[a]	1143.1[a]
LSD (0.05)	1.88	182.3	64.1
MC rate (g per hectare)			
0	30.04[b]	2926.3[b]	1034.5[b]
48 + 24	32.90[a]	3206.1[a]	1130.5[a]
LSD (0.05)	1.33	128.9	45.4
SD	3.79	367.9	129.4
CV %	12.04	12.0	12.0

Values followed by the same letter in a column are not significantly different from each other at P = 0.05.

Table 3. Effect of interaction between N rate and foliar application of K on yield combined over two seasons I and II.

Character	Seed cotton yield (g per plant)		Seed cotton yield (kg per hectare)		Lint yield (kg per hectare)	
K rate (g per hectare)	N rate (kg per hectare)					
	95	143	95	143	95	143
0	27.04^{d}	30.18^{c}	2639.2^{d}	2945.8^{c}	936.0^{d}	1040.3^{c}
319	29.73^{c}	33.28^{ab}	2896.6^{c}	3240.5^{ab}	1025.3^{c}	1141.5^{ab}
638	30.16^{c}	34.86^{a}	2935.5^{c}	3390.4^{a}	1037.2^{c}	1193.3^{a}
957	31.38^{bc}	35.11^{a}	3058.0^{bc}	3423.3^{a}	1081.4^{bc}	1204.7^{a}
LSD (0.05)†	2.66		257.8		90.7	

Values followed by the same letter in columns under every character head are not significantly different from each other at P = 0.05; †LSD, Least significant difference.

Table 4. Effect of interaction between N rate and foliar application of MC on yield combined over two seasons I and II.

Character	Seed cotton yield (g per plant)		Seed cotton yield (kg per hectare)		Lint yield (kg per hectare)	
N rate (kg per hectare)	MC rate (g per hectare)					
	0	48 + 24	0	48 + 24	0	48 + 24
95	28.11^{c}	31.04^{b}	2739.1^{c}	3025.6^{b}	970.4^{c}	1069.5^{b}
143	31.96^{b}	34.75^{a}	3113.5^{b}	3386.5^{a}	1098.5^{b}	1191.4^{a}
LSD (0.05)†	1.88		182.3		64.1	

Values followed by the same letter in columns under every character head are not significantly different from each other at P = 0.05; †LSD, Least significant difference.

Table 5. Effect of interaction between K rate and foliar application of MC on yield combined over two seasons I and II.

Character	Seed cotton yield (g per plant)		Seed cotton yield (kg per hectare)		Lint yield (kg per hectare)	
K rate (g per hectare)	MC rate (g per hectare)					
	0	48 + 24	0	48 + 24	0	48 + 24
0	27.22^{c}	29.99^{b}	2655.0^{c}	2930.0^{b}	941.1^{c}	1035.3^{b}
319	29.66^{bc}	33.35^{a}	2891.3^{bc}	3245.8^{a}	1022.0^{bc}	1144.9^{a}
638	31.00^{b}	34.03^{a}	3014.1^{b}	3311.8^{a}	1064.2^{b}	1166.3^{a}
957	32.28^{ab}	34.21^{a}	3144.7^{ab}	3336.6^{a}	1110.7^{ab}	1175.5^{a}
LSD (0.05)†	2.66		257.8		90.7	

Values followed by the same letter in columns under every character head are not significantly different from each other at P = 0.05; †LSD, Least significant difference.

nificant between treatment combinations regardless of the non-significance of the interaction effects from the ANOVA, to reach a balance between experience and level of statistics as shown in **Tables 3-6**. It is quite possible that the experimental error could mask the pronounced effects of the interactions.

In this manner, we found from the results that, if there were no significant differences existed between the different levels of any main factor (N, K or MC), in such case if the Least Significant Difference was calculated, the significance would not be existed. On the other hand, if the significance of the interactions between the main factors (first & second order interactions) did not existed, the estimation of Least Significant Difference of the interactions between the main factors, could give significant result.

Thus, it could be said that the formula used in calculating the significance of interactions suffers a possible shortage.

We think that, it could be useful to modify or add

Table 6. Effect of interactions between N rate, foliar application of K and MC on yield in cotton combined over two seasons I and II.

Treatment			Seed cotton yield (g per plant)	Seed cotton yield (kg per hectare)	Lint yield (kg per hectare)
N rate (kg per hectare)	K rate (g per hectare)	MC rate (g per hectare)			
95	0	0	25.54^{e}	2490.4^{e}	884.4^{e}
		48 + 24	27.85^{de}	2716.3^{de}	963.2^{de}
	319	0	28.71^{de}	2793.6^{de}	987.6^{de}
		48 + 24	30.36^{cd}	2956.1^{cd}	1046.7^{cd}
	638	0	28.54^{de}	2788.0^{de}	987.6^{de}
		48 + 24	31.62^{bcd}	3077.0^{bcd}	1087.4^{bcd}
	957	0	31.62^{bcd}	3077.4^{bcd}	1086.7^{bcd}
		48 + 24	32.40^{bc}	3160.0^{bc}	1116.2^{bc}
143	0	0	28.91^{cd}	2819.7^{cd}	997.8^{cd}
		48 + 24	31.48^{bcd}	3066.3^{bcd}	1080.8^{bcd}
	319	0	33.28^{ab}	3234.7^{ab}	1140.8^{ab}
		48 + 24	34.20^{ab}	3333.4^{ab}	1174.7^{ab}
	638	0	31.45^{bc}	3072.0^{bc}	1082.9^{bc}
		48 + 24	35.08^{ab}	3414.7^{ab}	1202.3^{ab}
	957	0	36.44^{a}	3546.2^{a}	1245.8^{a}
		48 + 24	36.03^{a}	3513.2^{a}	1234.8^{a}
LSD (0.05)†			3.76	364.6	128.3

Means followed by the same letter in a column are not significantly different from each other at $P = 0.05$; †LSD, Least significant difference.

some additions to the original formula used for calculating F values of interactions:

F = Mean square for interaction / Mean square for error

In this connection, we could suggest that when calculating the significance of interactions we could calculate it as follow:

F = Mean square for interaction × n / Root of mean square for error (suggested formula)

where n = number of main factors in the interaction.

We strongly believe that the use of the suggested formula, would secure the disclosure of the significant effects of the interactions regardless of the high experimental error.

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