

Effect of Split Application of Nitrogen Fertilizer on the Growth, Yield and Protein Content of Wheat

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ABSTRACT. Field experiments were conducted at two locations and in two seasons, 1985-86 and 1986-87, to study the effect of split application of nitrogen fertilizer on the growth, yield and protein content of wheat. The treatments tested included an unfertilized control, applying the fertilizer (160 kgN/ha) in one dose at sowing, in two splits at sowing and at tillering, three splits at sowing, tillering and booting, and four splits at sowing, tillering, booting and flowering. The effect of treatments on growth parameters, yield, yield components and protein content was studied. The unfertilized control was significantly the lowest in growth and yield. The tested parameters showed that split application of N fertilizer was superior to the application in one dose. Applying N fertilizer in three equal doses at sowing, tillering and booting gave the highest grain yield of wheat. A fourth split given at the time of flowering increased the protein content of grains.

The production of wheat (*Triticum aestivum* L.) in Saudi Arabia has been increasing sharply during the last decade. However, agronomic research on grain wheat is still very scanty especially in the Eastern Province of the Kingdom. Substantial amounts of N fertilizer are applied to wheat in Saudi Arabia but the exact dosage and time of application are very variable. In general, it is accepted among the farmers that split application of fertilizer into a number of small doses is a useful practice. But the number of these doses, as currently practiced by farmers, is still also variable and there is no experimental evidence to support the validity of any particular practice.

The importance of available soil N to the wheat crop has long been recognized, not only for yield but also for increased protein content of the grain (Simkins *et al.* 1977, Nedelciuc *et al.* 1986, Makki *et al.* 1987).

According to Haunold *et al.* (1962), most of the plant nutrients derived from the soil are taken up before the plant blooms, being later translocated to the kernel, but N uptake may continue until the grain is ripe. Investigations by Simkins *et al.* (1977) showed that a major portion of the plant nutrients is taken up by the wheat plant during the stage from tillering to heading.

Splitting of N fertilizer has been investigated in many studies. However, discrepancies exist in results concerning the number of N doses applied to wheat. Clapp (1973) and Westcott *et al.* (1984) found that splitting of N fertilizer did not give higher yields than single dressing. Two dressings, at planting and in the spring, were found to give the highest yields. Later applications may result in a greater increase in the protein content of the grain. Amongst different treatments Gill and Ahmad (1985) found two dressings at sowing and tillering to give the highest yield. Applying N in 1-4 split dressings showed that three split dressings gave the highest yields. (Chillar and Dargan 1982).

An extension bulletin in Saudi Arabia recommended a rate of 180 kg N/ha to be applied to wheat grown under center pivot in two doses; half at sowing and the other half 4-6 weeks after sowing. It was added that researchers further recommended the same rate to be applied with irrigation water in three or four splits in order to provide the plants with fertilizer throughout the growing season (Anon 1984). However, this work was raised to study the effect of split application of fertilizer nitrogen on the growth, yield and quality of wheat, in an attempt to make recommendations based on direct experimental evidence.

Materials and Methods

Four experiments were conducted in two successive seasons, 1985-86 and 1986-87, and at two locations King Faisal University Research Station (KFU) and Hassa Irrigation and Drainage Authority Station (HIDA). The two sites represent the new soils which had been reclaimed from the desert recently and the old more fertile farms traditionally cultivated by the farmers, respectively. Both soils are poor in organic matter (0.4%) low in nitrogen (0.02%), mildly alkaline (7.64) and contain moderate amounts of soluble salts (EC 3.9).

The experiments included four split application treatments as follows:

1. Control (ON)
2. All dose (160 kg N/ha) applied at sowing
3. 1/2 dose at sowing + 1/2 at tillering
4. 1/3 dose at sowing + 1/3 at tillering + 1/3 at booting.
5. 1/4 dose at sowing + 1/4 at tillering + 1/4 at booting + 1/4 at flowering.

Nitrogen was applied in the form of urea (46.2% N), hand drilled between the rows and watered in by immediate irrigation. All plots received a basal dressing of 80 kg P₂O₅/ha as trisuperphosphate applied at the time of sowing and a mixed dose of micronutrients containing Cu, Zn, Mn and Fe; at the rate of 2 kg/ha of each one of the four microelements. The experimental design used was randomized blocks with four replications.

Wheat of the variety Westbred, one of the standard commercial varieties in the area was sown in early November at the rate of 100 kg/ha in rows 20 cm apart.

The growth and yield attributes measured included: height, flag leaf area, spike weight, numbers of spikelets, number of kernels, 1000 grain weight, dry weight, total grain and straw yield and protein content of the grain.

Results and Discussion

Effects of Plant Growth

As shown in Table 1 treatments had a statistically significant effect, at the 1% level, on dry weight in both locations and seasons. Application of N fertilizer as a whole dose at sowing resulted in lower dry weights than split application, indicating that split doses made more N available for growth and dry matter production. This effect was also reflected in the final straw yield.

The upper most leaf of wheat, the flag leaf, has been closely associated with the grain yield of cereal crops (Arnon 1972). The effect of treatments on flag leaf area (Table 2) showed close similarity with the effects on dry weight. Applying all the fertilizer in one dose resulted in lower flag leaf area than split applications.

Effects on yield components

The effects of split application treatments on yield components are presented in Table 3. The number of spikelets per spike was affected significantly at the 1%

Table 1. The effect of split application treatments on the dry weight of wheat plants per unit area in the two locations and two seasons, 1985-86 and 1986-87 (gm/m²)

Treatment	1985-86		1986-87		Mean
	KFU	HIDA	KFU	HIDA	
Control	435.0	975.0	622.5	1281.8	828.6
Whole dose at S*	1264.1	1497.9	1037.8	1742.3	1385.5
1/2 S + 1/2 T	1786.8	1897.9	1672.0	1973.8	1832.6
1/3 S + 1/3 T + 1/3 B	1562.4	1803.2	1780.0	1932.0	1769.4
1/4 S + 1/4 T + 1/4 B + 1/4 F	1697.2	1839.0	1773.0	1809.5	1779.7
Mean	1349.1	1602.6	1377.1	1747.9	
S.E. \pm	206.76	212.4	151.82	255.56	
LSD 5%	450.5	463.0	330.8	556.85	
1%	631.7	649.2	463.8	780.72	

*S = Nitrogen fertilizer applied at sowing
 T = Nitrogen fertilizer applied at tillering
 B = Nitrogen fertilizer applied at booting
 F = Nitrogen fertilizer applied at flowering

Table 2. The effect of split application treatments on the flag leaf area of wheat plants in the two locations and two seasons, 1985-86 and 1986-87 (cm²/leaf)

Treatment	1985-86		1986-87		Mean
	KFU	HIDA	KFU	HIDA	
Control	5.82	13.40	11.84	18.17	12.31
Whole dose at S*	11.98	21.48	18.94	21.93	18.58
1/2 S + 1/2 T	18.81	31.38	31.22	24.93	26.59
1/3 S + 1/3 T + 1/3 B	12.15	21.68	28.33	25.72	21.98
1/4 S + 1/4 T + 1/4 B + 1/4 F	20.50	22.36	24.51	21.18	22.14
Mean	13.85	22.06	22.97	22.39	
S.E. \pm	4.236	3.255	2.466	2.908	
LSD 5%	9.230	7.093	5.373	N.S	
1%	12.941	9.944	7.534	N.S	

*S = Nitrogen fertilizer applied at sowing
 T = Nitrogen fertilizer applied at tillering
 B = Nitrogen fertilizer applied at booting
 F = Nitrogen fertilizer applied at flowering

Table 3. The effect of split application treatments on the yield components of wheat in the two locations and two seasons, 1985-86 and 1986-87

Treatment	No. of ears/m ²				No. of spikelets/spike				No. of kernels/spike				1000 grain wt (gm)			
	1985-86		1986-87		1985-86		1986-87		1985-86		1986-87		1985-86		1986-87	
	KFU	HIDA	KFU	HIDA	KFU	HIDA	KFU	HIDA	KFU	HIDA	KFU	HIDA	KFU	HIDA	KFU	HIDA
Control	333	500	383	563	14	16	17	21	24	26	34	44	43.42	40.76	43.11	40.77
Whole dose at S*	388	545	510	590	22	21	21	21	42	44	45	47	45.31	43.14	44.00	40.10
1/2 S + 1/2 T	485	613	520	660	22	22	22	21	45	46	49	45	44.24	42.28	43.62	39.07
1/3 S + 1/3 T + 1/3 B	398	628	523	648	22	22	22	22	50	46	58	48	44.28	42.78	41.77	41.54
1/4 S + 1/4 T + 1/4 B + 1/4 F	510	598	555	640	21	21	21	20	50	46	58	41	47.22	44.33	45.09	42.22
Mean	423	577	498	620	20	20	21	21	42	42	49	45	44.89	42.66	43.52	40.74
S.E. ±	63.4	111.4	85.2	119.5	1.1	0.8	0.4	0.47	2.7	2.7	2.4	1.9	0.886	0.852	1.030	1.039
LSD 5%	N.S	N.S	N.S	N.S	2.4	1.8	0.9	N.S	5.9	5.9	5.3	4.2	1.931	1.857	N.S	N.S
1%	N.S	N.S	N.S	N.S	3.4	2.6	1.3	N.S	8.4	8.3	7.4	N.S	2.707	N.S	N.S	N.S

*S = Nitrogen fertilizer applied at sowing

T = Nitrogen fertilizer applied at tillering

B = Nitrogen fertilizer applied at booting

F = Nitrogen fertilizer applied at flowering

level in both seasons and at HIDA. The unfertilized treatment showed lower numbers than all other treatments which did not differ significantly from each other.

The number of kernels per spike showed a significantly consistent trend of increase with split application of N; the more the splits, the more was the number of kernels per spike.

Fertilizer treatments did not show statistically significant effects on the number of ears per unit area. There were, however, slightly lower numbers of ears in the unfertilized control and the whole dose as compared with split application treatments.

The effect of treatments on 1000-grain weight was significant in the first season only. In both locations application in four splits resulted in slightly higher 1000-grain weights. The explanation is offered that N applied late, at the time of flowering, contributed more to the observed increase in grain weight.

The effect of treatments on ear weight was highly significant in all experiments. There was a gradual increase in ear weight from the control up to the three split treatment which was not statistically different from four splits.

Effects on grain yield

Statistical analysis of variance of the data on grain yield was made on yearly basis and as a combined analysis for all seasons and locations. The effects (Table 4) were highly significant in all experiments. There was a gradual increase in yield from the control to application of N in three splits which consistently gave the highest yield. Four splits resulted in slightly lower yield than the two or three splits. The results presented clear evidence of the superiority of split application of N fertilizer to wheat. It is believed that split application caters for adequate growth throughout the growing season.

The combined analysis of variance showed significant differences in the main effects of treatments, locations and years and all the two factor interactions. This indicates that the response of grain yield to treatments was not the same in different years and different locations. This can be attributed to the combine effect of both soil and climatic variations.

Protein content of the grain

The effect of treatments on protein content was highly significant. The unexpectedly high values for the control at KFU were associated with the plants

Table 4. The effect of split application treatments on grain yield of wheat in the two locations and two seasons, 1985-86 and 1986-87 (t/ha)

Treatment	1985-86		1986-87		Mean
	KFU	HIDA	KFU	HIDA	
Control	1.43	3.46	2.54	3.71	2.79
Whole dose at S*	4.47	6.58	3.49	5.42	4.99
1/2 S + 1/2 T	6.16	6.66	5.63	6.00	6.11
1/3 S + 1/3 T + 1/3 B	6.55	7.53	6.68	6.34	6.78
1/4 S + 1/4 T + 1/4 B + 1/4 F	5.77	7.08	6.54	6.05	6.36
Mean	4.88	6.26	4.98	5.50	
S.E. \pm	0.336	0.519	0.373	0.509	
LSD 5%	0.732	1.131	0.813	1.109	
1%	1.026	1.586	1.140	1.555	

*S = Nitrogen fertilizer applied at sowing
T = Nitrogen fertilizer applied at tillering
B = Nitrogen fertilizer applied at booting
F = Nitrogen fertilizer applied at flowering

being under stress resulting in poor grains and low yield, and consequently high protein (Hoseney 1986).

Protein content of the grain exhibited a general trend of gradual increase for the treatments which received N, from the one in which N was applied as a whole dose throughout the range of split applications (Table 5).

In discussing the results obtained as a whole it becomes evident that nitrogen which is an essential macroelement of direct relevance to growth is utilized much better when made available to the plant throughout the growing season. This was clearly reflected in this study by the superiority of split application as compared with the control and the whole dose at sowing as exhibited by dry weight, straw yield and leaf area. The effect of growth extended to some yield components and ultimately final yield.

Correlation analysis showed that among the yield components studied, the number of kernels per spike and ear weight made the primary contribution to the increase in yield as a result of split application of N. These two are the components which were consistently and significantly affected by split application treatments. The number of ears per unit area was adversely affected when N was not applied in split doses.

Table 5. The effect of split application treatments on the protein content of the grain in the two sites and two seasons, 1985-86 and 1986-87 (% on dry matter basis)

Treatment	1985-86		1986-87		Mean
	KFU	HIDA	KFU	HIDA	
Control	11.24	10.10	10.62	10.57	10.63
Whole dose at S*	9.20	10.61	9.91	12.05	10.44
1/2 S + 1/2 T	9.83	11.76	10.87	12.43	11.22
1/3 S + 1/3 T + 1/3 B	11.08	12.56	12.00	13.60	12.31
1/4 S + 1/4 T + 1/4 B + 1/4 F	13.10	12.81	14.06	14.22	13.55
Mean	11.03	11.57	11.49	12.57	
S.E. \pm	0.239	0.958	0.470	0.636	
LSD 5%	0.521	0.998	1.024	1.386	
1%	0.730	1.399	1.463	1.943	

*S = Nitrogen fertilizer applied at sowing
T = Nitrogen fertilizer applied at tillering
B = Nitrogen fertilizer applied at booting
F = Nitrogen fertilizer applied at flowering

Two of the components which tended to increase with very late application of N are 1000 grain weight, though not consistently, and protein content. Nitrogen is known to be translocated inside the plant from the lower leaves to new growth and to the grains later in the season. This was clearly reflected in the four-split application treatments in which the last dose was at flowering. It resulted in the highest protein content in the grain in all experiments and consequently gave higher protein yield. High N content in the soil and high availability of N late in the growing period, during the reproductive stages, are known to increase protein content in the grain (Hagras 1981).

Considering the combined effects on the important parameters of growth, yield and quality, the application of N fertilizer to wheat in three split doses throughout the growing season seems to satisfy the requirements of an optimum treatment most.

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(Received 24/06/1990;
in revised form 08/06/1991)

أثر تجزئة السماد النيتروجيني على نمو وانتاج القمح وعلى محتوى الحبوب من البروتين

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المملكة العربية السعودية

لقد اشتمل البحث على تجارب حقلية أجريت لمدة موسمين ٨٥ - ١٩٨٦ و ٨٦ - ١٩٨٧ م في موقعين واشتملت التجارب على المعاملات التالية: معاملة المقارنة بدون سماد، وضع السماد على دفعة واحدة عند الزراعة، وضع السماد على دفعتين متساويتين عند الزراعة وفي ميعاد ظهور الخلفات، وضع السماد على ثلاث دفعات عند الزراعة وعند ظهور الخلفات وفي طور طرد السنابل، وضع السماد على أربع دفعات عند الزراعة وعند ظهور الخلفات وفي طور طرد السنابل وعند مرحلة التزهير.

ولقد دلت النتائج على أن تجزئة السماد تتيح كميات أوفر من النيتروجين للنمو وانتاج الوزن الجاف. ولقد اظهرت المعاملة التي وضع السماد فيها على دفعتين أعلى مساحة لورقة الراية وكانت هناك زيادة تدريجية في الوزن النهائي للقش مع معاملات تجزئة السماد.

أما بالنسبة لمكونات محصول الحبوب فقد كان هناك اتجاه لزيادة عدد الحبوب في السنبله مع زيادة تجزئة السماد النيتروجيني. ولم يتأثر عدد السنيبلات في السنبله الواحدة بمعاملات تجزئة السماد. ولقد أدت المعاملة التي وضع فيها السماد على

أربع دفعات إلى زيادة منتظمة في وزن الالف حبة، مما يشير إلى أن وضع السماد في ميعاد التزهير يسهم في زيادة وزن الحبة.

ولقد أجري تحليل احصائي مشترك، ضم النتائج التي تم الحصول عليها في الموسمين، وفي الموقعين معا، وأظهر هذا التحليل تأثيراً معنوياً عالياً للمعاملات على إنتاج الحبوب، ودلت النتائج بوضوح على تفوق وضع السماد على دفعات بالنسبة لمحصول القمح.

وحققت المعاملة التي وضع فيها السماد على ثلاث دفعات متساوية في ميعاد الزراعة، وظهور الخلفات، وطرده السنابل على أعلى قدر من إنتاج الحبوب. كما كان هنالك تأثير معنوي عالٍ للتفاعل الثنائي بين المعاملات والمواقع، والمواسم، مما يشير إلى أن استجابة القمح للمعاملات قد تختلف من موسم إلى آخر، ومن موقع إلى آخر.

أما بالنسبة لما تحتويه الحبوب من البروتين فقد كانت هناك زيادة تدريجية في المحتوى البروتيني للحبوب نتيجة للمعاملة التي وضع فيه السماد في دفعة واحدة وعلى امتداد معاملات تجزئة السماد، ونتج عن وضع السماد على أربع دفعات منذ الزراعة حتى الازهار أعلى محتوى بروتيني في الحبوب في جميع التجارب الأربع مما يشير إلى أنه إذا كانت هناك قيمة إضافية لإرتفاع نسبة البروتين في الحبوب، فيمكن وضع السماد على أربع دفعات متساوية بحيث يكون آخرها عند الازهار.