EFFECT OF NITROGEN FERTILIZER RATES ON YIELD, YIELD COMPONENETS AND GRAIN QUALITY MEASUREMENTS OF SOME WHEAT CULTIVARS USING SPAD-METER

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Abstract

Two field experiments were carried out at Agric. Res. Station, Agric. Res. Centre, Giza Governorate, Egypt during 2006/2007 and 2007/2008 growing seasons. The aim of this study was to find the relationships between fertilization rates and SPAD readings and economic N application to minimize pollution and cost, and maximize wheat growth and yield. Three bread wheat genotypes namely Sakha 94, Giza 168 and Gemmiza 9 and five N fertilization treatments, i.e., 0, 40, 80 kg N/fad (as a recommended N rate) and 120 kg N/fad as high rate as well as N applied according to SPAD measurements, nitrogen sufficiency indices (NSI).

The results showed gradual remarkable increase in SPAD values versus advancing wheat plant towards maturity till reached their maximum values at early grain filling stage, i.e., 118 days from planting. On the other hand, the relationship between SPAD readings and N rates indicated that wheat plants received either 80 kg N/fad or N fertilizer according to NSI had statistically the same values of yield and its components with insignificant discrepancy between them. The results clearly indicated that the studied characters were significantly affected by increasing N fertilizer rates except for harvest index. The increment of grain and biological yields via N fertilization rates was accompanied with rising crude protein yield. The results indicated significant increases in crude protein, wet and dry gluten versus increasing N fertilizer rates till reached their maximal values at a level of 80 kg N/fad or according to NSI. A positive relationship between grain protein content and both wet and dry gluten was found. The rate of increase in wet gluten was lower than that of dry gluten, therefore, the hydration value was significantly decreased. In conclusion, the use of SPAD meter and NSI was very important to detect the nitrogen physiological rate for growth, yield and grain quality of wheat plant. Moreover, the use of NSI economized the cost of nitrogen fertilizer by rate of about 25% and more reliable for production of wheat without effect on wheat yield.

Key words: Wheat genotypes, SPAD measurements, Nitrogen fertilizer rates, Grain quality.

INTRODUCTION

Cultivated soils over Egypt are deficient in available nitrogen and organic matter, and their removal is usually greater than their input. In the quest of achieving high yield of wheat, farmers tend to apply nitrogen in excess of the requirements. This is attained to spreading millions of tons of nitrogenous fertilizers manufactured at high cost. It is well known that excess N availability for crops like wheat and barely can adversely affect plant health, yield , values of the final product and environmental pollution.

Brown *et al* (2005)and Hussain *et al* (2006) showed that increase N levels had significant positive effects on plant height, total number of plants/m^2, number of grains/spike, number of spikes/m^2, spike weight, biological, grain and protein yields, 1000-grain weight, grain protein percentage and its related characters, i.e., wet and dry gluten percentages.

Application of chlorophyll meter technology needs to be examined in terms of plant growth characteristics and N management goal. The chlorophyll meter, also known as SPAD (soil plants analysis development) meter could be quickly and reliably assess the nitrogen status of a cultivar based chlorophyll content of wheat flag leaf during phenological stages of growth. Therefore, SPAD meter is one of the most profitable methods that have its greatest sensitivity in the deficient to adequate range of N nutrition. As such, the meter cannot indicate how much excessive N is available to a crop. Its strength lie in measuring a relative difference in crop N status of the treatment under question and over nitrogen fertilized strip to detect the disadvantage and calculate the rate of nitrogen need to maximize the crop yield and evaluate its usefulness for predicting the grain yield.

Spaner *et al* (2005) reported that plant need-based N management approaches may increase the efficiency of N fertilizer application in wheat (*Triticum aestivum* L.). The leaf chlorophyll concentration estimated through the described relationship between winter wheat grain yield, protein content, protein yield and SPAD measurements as affected by differential stage of crop growth and topdress N fertilizer. Grain yield, protein content, and protein yield of winter wheat exhibited linear responses to increasing N topdress application rate. SPAD-502 values were moderately to highly positively correlated with grain yield, protein content, and protein yield as a result of increasing topdress N fertilization, and moderately negatively correlated as a result of increasing seeding rate. It may be difficult to make an N-application rate recommendation based on SPAD measurements, as a critical SPAD value may vary among years, locations, cultivars and soil characters.

SPAD readings indicate that plant N status and the amount of N to be applied are determined by the physiological N requirement of crops at different growth stages. Singh *et al* (2002) and Zagórda *et al* (2007 showed that plant need-based N management through chlorophyll meter reduced N requirement from 12.5 to 25%

with no loss in yield as compared with typical growers practices. Therefore, the objectives of the present investigation were designed to determine economic optimum N fertilization rates and economic N application to minimize pollution and cost, and to maximize grain yield and, yield components, nitrogen physiological parameters and grain quality.

MATERIALS AND METHODS

Two field experiments were carried out at the Agric. Res. Station of Giza. Agric. Res. Centre, Giza Governorate, Egypt during 2006/2007 and 2007/2008 growing seasons. The physical and chemical characteristics of the experimental soil before planting was carried out according to Jackson (1973) and the data are shown in Table 1.

Table 1. Some Physical and chemical characteristics of Expt. soil. Average of 2006/2007 and 2007/2008 growing seasons.

Mechanical analysis(%)	Average	Chemical analysis	Average
Coarse sand	7.0	Organic matter %	2.0
Fine sand	27.2	pH	7.6
Silt	19.5	$CaCO_3$ (%)	3.1
Clay	46.4	Nutrients (mg/kg soil)	
Soil Texture	Clay soil	Total N	61.2
		P	8.6
		K	295.7

Each experiment included 15 treatments, which were the combinations of three bread wheat genotypes namely Sakha 94, Giza 168 and Gemmiza 9, obtained from Wheat Dept., Agric. Res. Centre at Giza and five fertilization treatments, i.e., 0, 40, 80 kg N/fad (as a recommended N rate),120 kg N/fad (as unlimited N fertilization rate) and N applied according to nitrogen sufficiency index (NSI) based on SPAD measurements. It was applied by adding initial rate of 20% of the recommended nitrogen rate and optimum N requirements was added just before every irrigation based on leaf chlorophyll status in relation to unlimited N fertilization strip using chlorophyll meter (Minolta-502 SPAD meter).

The experimental design used was strip plot design in four replications, where wheat genotypes were arranged in vertical strips and N fertilization rates were allocated in the horizontal strips. The experimental unit area was 10.5 m^2 consisting of 15 rows each of 3.5 m in length and 20 cm apart. The three N portions were added as doses equivalent to 20, 40 and 40% of total N amount, just before the first, second and third irrigations.

Nitrogen fertilizer was applied as urea (46% N) and all recommended cultural practices except for the studied input N were applied. The planting date was on 25 November in the two growing seasons, whereas harvest day was on 10 May.

Data recorded during growth

1- SPAD value

SPAD value was determined using Minolta SPAD meter periodically just before irrigation. Collection of the individual readings was carefully to ensure their accuracy. Avoid taking readings from plants that were not representative of the crop. Individual ten readings were determined from the middle of flag leaf of 10 plants from each plot in four replications to collect 40 readings from each treatment whose average represented the SPAD value of the treatment. According to Murdock *et al* (2004), the crop N application was based to calculate of nitrogen sufficiency index (NSI) according to the following equation :

$$NSI = \frac{\text{SPAD value with N treatment}}{\text{SPAD value of the sufficient N rate}} \times 100$$

When N sufficiency index was lower than 95 % indicates an N deficiency and additional N should be added using the following equation According to Murdock *et al* (2004):

$$N = 6 + (7 \times D)$$

Where:

N = N (lb/acre) needed for optimum growth

D = Difference between average chlorophyll readings from the treatment and the N-enriched reference area.

Data recorded at harvest

1. A sample of plants from 0.2 m^2 was chosen at random from each plot in three replications to determine number of spikes (m^2), spike length (cm), spikes weight (g/m^2) grain number per spike, spiklets number per spike and 1000-grain weight (g).

2. Grain, straw and biological yields (kg/fad) were calculated from all the plants of each plot.

3. Crude protein yield (kg/fad) = (grain yield × GCPC) / 100

4. Harvest index = (grain yield × 100) / biological yield.

5. Nitrogen physiological parameters

Nitrogen physiological parameters including N recovery efficiency (NRE, %), N use efficiency (NUE), nitrogen harvest index (NHI) and nitrogen physiological efficiency (NPE) were calculated according to Singh *et al* (2002) using the following equations:

$$5.1\ \text{NRE}\ \% = \frac{\text{TNU in N treatment} - \text{TNU in zero N}}{\text{Quantity of N fertilizer applied (kg/fad)}} \times 100$$

Where:

TNU = Total nitrogen uptake

$$5.2\ \text{NUE} = \frac{\text{GY in N treatment} - \text{GY in zero N}}{\text{Quantity of N fertilizer applied (kg/fad)}}$$

$$5.3\ \text{NHI} = \frac{\text{GN in N treatment}}{\text{T N uptake applied at N treatment}} \times 100$$

$$5.4.\ \text{NPE} = \frac{\text{GY in N treatment}}{\text{TN absorbed in N treatment}}$$

Where:

GN = Grain nitrogen

TN = total nitrogen

6. Grain yield response index (GYRI) was calculated according to **Fageria and Filho (1999)** using the following equation:

$$\text{GYRI} = \frac{\text{GY under 80 kg N/fad} - \text{GY under 0 N level}}{\text{N level}}$$

Where:

GYRI= Grain yield response index

GY = Grain Yield

7. Chemical analysis

7.1. About 100 g of grains or straw from each treatment in three replications were dried at 105^{o}C and grinned into fine powder for the determinations of total nitrogen using micro-Kjeldahl apparatus according to AOAC (1995). The grain crude protein content in grains (GCPC) was calculated by multiplying the total nitrogen percentage by 5.7.

7.2. Wet, dry gluten percentage and hydration value were determined in fine ground seeds according to Pleshkof (1978). Wet and dry gluten were calculated as percentage of dry seeds. Hydration value was calculated as percentage of dry gluten.

8. Statistical analysis

The obtained data were subjected to proper statistical analysis of variance according to SAS (1995). LSD at 5% level of significance was used to differentiate between means. Data of the average of the three studied wheat cultivars of 2006/2007 and 2007/2008 growing seasons were subjected to homogeneity test of variance for calculating the combined analysis of the data.

RESULTS AND DISCUSSION

1. SPAD Measurements during phenological stages

Table 2 showed gradual remarkable increases in SPAD values versus advancing wheat plant towards maturity till reached their maximum values at early grain filling stage, i.e., 118 days from planting. As the plants aged to ripening stage, the SPAD values were substantially decreased. The SPAD value was at its minimal value at the control unfertilized treatment. It was gradually and significantly increased versus increasing N fertilization rate till reached their maximum values for wheat plants received 120 kg N/fad. Regarding Fig 1 It is worthy to note that the SPAD values of wheat plants received either 80 kg N/fad or N fertilizer according to NSI had statistically the same values with insignificant discrepancy between them at each growth stage.

The data in Table 2 show the mean SPAD values of wheat plant versus increasing N rates. The data revealed that at tillering stage, the SPAD values of flag leaf recorded 41.7 and 41.1, at elongation stage were 44.1 and 43.7, at heading stage were 47.9 and 47.5, at flowering stage were 50.1 and 50.0, at early grain filling were 50.9 and 50.6, at late grain filling stage were 48.5 and 48.0 at 80 and 59.8 kg N/fad as sum portions of N fertilizer added to the plants referred to NSI with insignificant differences among every two readings at every stage of growth.

Table 2. Effect of N fertilization rates (kg N/fad) on SPAD values of flag leaf of studied three wheat genotypes during growth stages. Average of 2006/2007 and 2007/2008 growing seasons.

N rates (kg/fad)	S_1 stage (46 d)	S_2 stage (75 d)	S_3 stage (90 d)	S_4 stage (109 d)	S_5 stage (118 d)	S_6 stage (130 d)	Average
0	37.9	40.1	43.3	45.3	46.6	44.8	43.0
40	39.3	41.7	45.2	46.9	48.1	46.3	44.6
59.8*	41.1	43.7	47.5	50.0	50.6	48.0	47.0
80	41.7	44.1	47.9	50.1	50.9	48.5	47.3
120	43.0	46.2	50.0	51.3	51.7	50.4	48.8
LSD at 5%	0.6	0.5	0.7	0.6	0.4	0.6	

* N rate determined by SPAD meter.

Where S_1, S_2, S_3, S_4, S_5 and S_6 are tillering, elongation, heading, flowering, early grain filling and late grain filling stages, respectively.

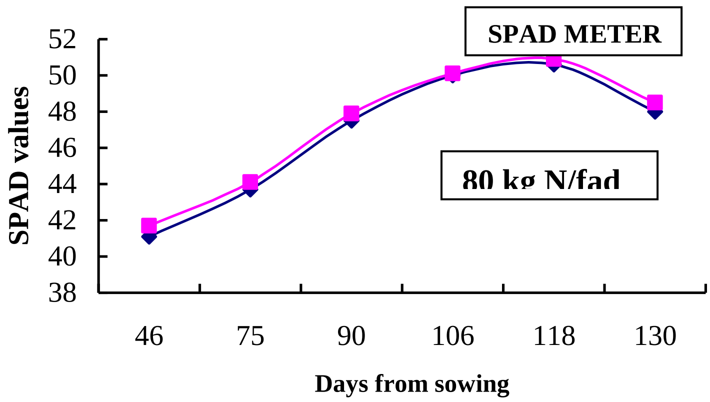

Fig 1. SPAD values of flag leaf of wheat plants received 80 kg N/fad and according to SPAD readings during growth. Average of the three cultivars (2006/2007 and 2007/2008 growing seasons).

2. Yield and its components

Results of the effect of N levels on spikes number/m^2, spike length (cm), spike weight(g/m^2), grain number /spike and spikelets number/spike are presented in Table3. The results indicated clearly that the above mentioned characters are significantly affected by N fertilizer. These characters significantly increased as a result of increasing N fertilizer from 0 to 40 , 59.8, 80 and 120 kg N /fad.

Table 3. Yield Components of the wheat cultivars** as affected by N fertilization rates (kg N/fad). Average of 2006/2007 and 2007/2008 growing seasons.

N rates (kg/fad)	Spikes No/m^2	Spikes length (cm)	Spikes wt. (g/m^2)	Grain No/spike	Spiklets No/spike
0	438.2	10.4	1016	51.0	19.6
40	483.7	11.1	1141	54.0	20.2
59.8*	549.1	11.5	1274	58.0	21.2
80	564.4	12.0	1420	59.8	21.9
120	585.9	12.5	1581	64.1	23.0
LSD at 5 %	11.7	0.2	100	1.3	0.5

* N rate determined by SPAD meter.

** Average of the three wheat cultivars.

It could be concluded that N encouraged tillering in wheat plants as a result of its vital role on photosynthetic activity in wheat plants and on plant growth. Similar results were obtained by Hussain *et al* (2006). They stated significant effect of increasing N rate on grain number /spike and spikes number/m^2.

Table 4 showed that N fertilizer rates significantly affected the yield of wheat plant. Grain yield of wheat plant at zero unfertilized treatment exhibited 2.41 ton/fad and significantly increased by rates of 11.2%, 28.2%, and 29.9% due to increasing N rate up to 40, 59.8, and 80 kg N/fad, respectively.

The biological yield exhibited 6.56 ton/fad for the control unfertilized treatment and increased by rates of 20.7, 42.7 and 49.0 % by increasing N rate to 40, 59.8, and 80 kg N/fad, correspondingly. The increment of grain yield via N fertilization rate was in positive relationship with crude protein yield.

The increment of grain yield via N fertilization rate was accompanied with rising crude protein yield. Table 4 revealed that crude protein yield was 288.2 kg/fad in the control unfertilized treatment. Increasing N rate up to 40, 59.8 (according to SI) and 80 kg/fad resulted in increase grain crude protein yield up to 342.5, 441.4, and 440.6 kg/fad versus increasing N rate, respectively., These increase percentages were 18.8, 53.2 and 52.9% for the above respective treatments. Meanwhile, harvest index was decreased to 33.9 33.1, and 32.1% by increasing N rate to 40, 59.8and 80 kg N/fad, respectively comparing to 36.6% at the control unfertilized treatment.

Table 4. Effect of N fertilization rates (kg N/fad) on grain, biological and grain crude protein (GCP) yields (kg/fad) and harvest index (HI, %) of the studied three wheat genotypes. Average of 2006/2007 and 2007/2008 growing seasons.

N rates (kg/fad)	Grain yield (ton/fad)	Biological yield(ton/fad)	GCP Yield (kg /fad)	HI %
0	2.41	6.56	288.2	36.8
40	2.68	7.92	342.5	33.9
59.8*	3.09	9.36	441.4	33.1
80	3.13	9.77	440.6	32.1
120	3.35	10.74	513.6	31.3
LSD at 5 %	0.05	0.70	40.7	0.6

- N rate determined by SPAD meter.

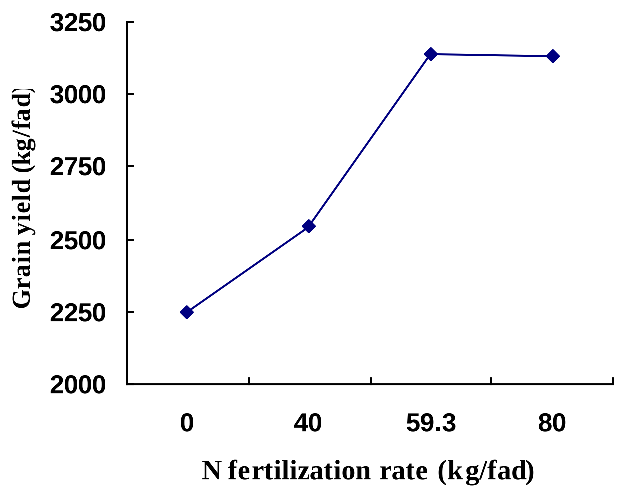

Fig. 3. Grain yield of wheat plant as affected by N fertilization rate. Average data of 2006/2007 and 2007/2008 growing seasons.

In this respect, David et al (1999), Sobh et al (2000), Ehdaie and Waines (2001) pointed out that the increase in grain and biological yields as a result of increment N rates explained that wheat plant used N to produce more dry matter. In addition, it could be assumed that the economics of wheat depends on two parameters namely: the relative yield of wheat as determined by N treatments and according to NSI supply with crop nitrogen demand.

Quality measurements

Table 5 showed that as N fertilizer increased the biosynthesis and mobilization of nitrogenous and soluble carbohydrates compounds and their polymerization in grains increased. Therefore, it was corresponded with increase grain size and 1000-grain weight for instance, 1000-grain weight increased from 38.0 g at unfertilized control treatment up to 39.9, 42.0, and 43.5 g by increment N rate up to 40, 59.8 and 80 kg N/fad by rate of 5.0, 10.5 and 14.5 %, respectively. The results indicated significant increment in crude protein, wet and dry gluten as well as absorption ratio versus increasing N fertilizer rates till reached their maximal values at a level of 80 kg N/fad or according to NSI. Additionally, it was found a positive relationship between grain protein content and both of wet and dry gluten. It was monitored that the rate of increase in wet gluten was lower than that of dry gluten. Therefore, the hydration value was significantly decreased from 153.3% at the control unfertilized treatment to 145.8 and 146.9% for plants received 80 kg N/fad or according to NSI with slight differences them. These findings indicated clearly the positive relationship between N fertilization rate and gluten absorption rate.

It was also found an adverse relationship between grain crude protein content and hydration value. For instance, the higher the crude protein content from plots received 80 kg N/fad as N recommended rate, the higher the crude protein content (14.1 and 15.3%), and the higher the wet (37.1 and 41.5%) gluten, the dry gluten (15.0 and 17.3%) and the lower the absorption ratio (145.8 and 139.2%), respectively. It means less the ability of gliadins and glutenins to absorb water and swelling, which reflected negatively on loaf volume and some essential organoleptic characteristics of bread. The increase in crude protein content via increasing N rates means improvement the essential amino acids and subsequently the nutritional value of grains as well. These findings are corroborated with those obtained by Jaime *et al* (2001), El-Nagar (2003), Brown *et al* (2005) and Hussain *et al* (2006).

Table 5. Effect of nitrogen fertilization rates (kg/fad) on some technological properties of wheat grains**. Average of 2006/2007 and 2007/2008 growing seasons.

N rates (kg/fad)	1000-grain wt. (g)	GCP %	Gluten %		
			Wet	Dry	Hydration Value %
0	38.0	12.0	28.7	11.3	153.3
40	39.9	12.9	31.3	12.5	149.1
59.8*	42.0	14.3	36.3	14.7	146.9
80	43.5	14.1	37.1	15.0	145.8
120	44.9	15.3	41.5	17.3	139.2
LSD at 5%	0.5	1.4	1.4	0.7	8.5

* N rate determined by SPAD meter.

** Average of the three wheat cultivars.

Regarding the data in Table 5, it could be assumed that the wheat plants received either 80 kg N/fad or according to NSI had insignificant effect on the grains quality. It means that supplying wheat plants with N fertilizer requirements referred to NSI using SPAD measurements was a profitable treatment for economizing N fertilization from 80 kg N/fad to the physiological requirements of 59.8 kg N/fad without any effects on grain yield and its technological properties.

In conclusion, the use of SPAD meter and NSI was very important to decision the nitrogen physiological rate for growth and yield of wheat plant instead of N recommended rate (80 kg/fad). Therefore, the use of NSI is very important to economize the cost of nitrogen fertilizer by rate of about 25% and more reliable for production of wheat without significant effects on grain and biological yields.

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تأثير معدلات التسميد النيتروجينى على المحصول ومكوناتة وصفات جودة الحبوب لبعض أصناف القمح بإستخدام الكلوروفيل ميتر

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٢. *المعمل الفرعى لبحوث التصميم والتحليل الاحصائى مركز البحوث الزراعية*

أجريت تجربتان حقليتان فى محطة بحوث االجيزة – مركز البحوث الزراعية خلال موسمى النمو 2007/2006 ، 2008/2007 . وذلك لدراسة العلاقة بين معدل السماد النيتروجينى وقراءات جهاز SPAD للتعرف على المعدل الإقتصادى للنينروجين لتقليل التلوث وخفض التكاليف وزيادة نمو محصول القمح. تضمنت المعاملات التجريبية ثلاثة أصناف من القمح هى سخا 94 ، جيزة 168 وجميزة 9 وخمسة مستويات من السماد النتروجينى صفر ، 40 ، 80 ، 120 كجم/ف بالإضافة إلى التسميد تبعا لقراءات SPAD وكان التصميم المستخدم هو الشرائح المتعامدة فى أربعة مكررات.

أوضحت النتائج زيادة معنوية لقيم SPAD بتقدم النبات نحو النضج وبلغت أقصاها فى بداية مرحلة إمتلاء الحبوب (118 يوم من الزراعة) . ومن ناحية أخرى إتضح من قراءات SPAD ومعدلات التسميد النيتروجينى أن النباتات التى سمدت بمعدل 80 كجم /ف أعطت أحصائيا نفس قراءات المحصول ومكوناته عند تطبيق التسميد باستخدام قراءات SPAD كما أوضحت النتائج زيادة معنوية فى قراءات المحصول ومكوناته بزيادة معدلات التسميد النيتروجينى ما عدا معامل الحصاد. الزيادة فى محصول الحبوب والمحصول البيولوجى بزيادة معدلات التسميد النيتروجينى يكون مصحوبا بزيادة محصول البروتين الخام للحبوب. كما أدت زيادة التسميد النيتروجينى الى زيادة معنوية فى نسبة كل من البروتين الخام للحبوب ، الجلوتين الرطب والجاف حتى معدل 80 كجم/ف أو بإستخدام قراءات SPAD . كما وجدت علاقة موجبة بين نسبة البروتين الخام للحبوب وكل من نسبة الجلوتين الرطب والجاف . أما نسبة الزيادة فى الجلوتين الرطب كانت أقل من الزيادة فى نسبة الجلوتين الجاف مما أدى إلى إنخفاض معنوى فى نسبة تأدرت الجلوتين . وفى الخلاصة إتضح أن إستخدام جهاز قراءاتSPAD ونسبة NSI مهم جدا لتحديد معدل التسميد النيتروجينى تبعا للمعدلات الفسيولوجية للمحصول ولنمو ومحصول وجودة محصول القمح . كما أن إستخدام هذا المعدل يؤدى إلى إنخفاض تكلفة إستخدام السماد النيتروجينى بمعدل 25 % بدون أى تأثير على محصول القمح.