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Response of Wheat Yield, Its Components and Technological Characteristics to Different Nitrogen Rates and Planting Methods

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TWO FIELD trials were conducted at the Agricultural Experiment Station, Faculty of Agriculture Ain Shams University, Kalubia, Egypt during 2013/2014 and 2014/2015 growing seasons to investigate the response of wheat to nitrogen fertilizer rates under different planting methods. Each experiment contained twelve treatments which were the combination of four planting methods (broadcasting (conventional tilled flat method), rows (20cm apart), ridge (ridge width 60 cm) and bed (bed width 120 cm)) and three nitrogen fertilizer rates (60, 80 and 100 kg Nitrogen/ fad (faddan = 4200 m^2)). Design of experiments was split plot design with three replications where planting methods in the main plot and nitrogen rates in the sub plots. Data indicated that applying 100 kg N/fad gave the highest yield attributes, which reflected its yield parameters and produced significant maximum grain yield (3421.6 kg/fad) followed by 80 kg N/fad (3158.0 kg/fad) and 60 kg N/fad (2574.9 kg/fad). Applied 100 kg N scored maximal test weight, 1000 grain weight, vitreosness, wet and dry gluten. Highest number of grains per main spike was obtained when crop was sown on raised bed (68.33 grain/main spike) versus the minimal value in case of sowing broadcasting (58.78 grain/main spike). In addition, all studied yield parameters gave the highest valuses due to sowing on raised bed than others planting methods. Grain, straw and biological yields were at maximal values when wheat plants sown on raised bed being 3334.0, 5175.6 and 8487.4 kg/fad, respectively. On other hand, vitreosness, wet and dry gluten scored the highest values when wheat plants were sown in broadcasting. Meanwhile, the application of 80 kg N/fad exhibited maximum values of main spike weight (6.08 g) and grains No of main spike (72.33 grains/main spike) with sowing wheat plants on raised bed. Grain yield was at the maximal values (3604.0 kg/fad) when wheat plants were sown on raised bed with application of 80 kg N/fad. Test weight, 1000-grain weight, and dry gluten were significantly varied among nitrogen fertilizer rates and sowing methods.

Keywords: *Triticum aestivum*, Wheat, Planting methods, Nitrogen rates, Yield, Yield components and Technological characteristics.

Introduction

Wheat is the essential crop in Egypt and grows on an area of 3.39 million faddan (faddan = 4200m^2) with an annual production of about 9.28 million tones and with an average yield of 2.74 tons per faddan during 2014/2015 growing season (CLAC, 2015). Raised bed 140 cm wide significantly increased grain and straw yields by 16 and 18% compared to flat (traditional method) (El-Hadidi et al., 2015).

Agriculture on beds gave the highest grain yield (Hossain et al., 2006 and Khaleque et al., 2008). Kilic (2010) found that yield and its components significantly affected by planting methods, thousand grain weight, number of grains/ spike (53.8) and weight of grains spike (2.4 g) were highest in the bed planting method. Raised beds (70 cm) increased yield and its components of wheat, as the prevalence of herbs decreased and reduced water consumption by 41-48 %. The final costs have decreased and therefore the profit margins have increased with agriculture on the beds compared to the traditional method (Mollah et al., 2009; Mollah et al., 2015 and Yildirim et al., 2016). Wheat cultivation on beds is a way to improve resource efficiency and increase yields and

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the land is prepared for cultivation in manually or automatically way. Wheat is grown in rows above bed and irrigation is done in grooves between raised beds.

Supply of nutrients in a suitable form is also a major determining factor for cereal production. Nitrogen being the most important applied fertilizer, as wheat is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization. Nitrogen is an important agronomic factor which affecting the yield and technological quality, especially content and quality of protein and gluten (Podolska, 2014). With increasing nitrogen rates, the grain yield and other yield components will increase. Application of 100 kg N/ha, and 150 kg N/ ha gave the highest grain and straw yield. (Shukra et al., 2016). Optimal physical nitrogen rate in both seasons ranged from 290 to 339 kg/ha, whereas optimal economic nitrogen rate ranged from 248 to 274 kg/ha, with yields between 10.2 and 10.1 ton/ha. Nitrogen rate increased hectoliter weight and grain protein (Campillo et al., 2010).

Degradation of wheat plants occurs when increasing of nitrogen fertilization rates (Ma et al., 2010) and economic losses are also increasing for farmers, where only 33% of the nitrogen fertilizer added was absorbed by harvested grains (Raun & Johnson, 1999). Therefore, the optimum nitrogen fertilization rate for wheat should be determined to increase yield. For irrigated wheat, Heinman et al. (2006) recorded that positive response occurs with the application of 156 kg/ha of N which given a grain yield of 6472 kg/ha. Thus, the lack of nitrogen significantly affects the productivity of the wheat crop (Sarwar et al., 2012). The present investigation was organized to evaluate the behavior of wheat (*Triticum aestivum* L.) to nitrogen rates under different planting methods.

Materials and Methods

Two field experiments were carried out in Faculty of Agriculture, Ain Shams University Expt. Farm at Shalakan, Kaleobia Governorate, Cairo, Egypt during 2013/2014 and 2014/2015 growing seasons to study the response of bread wheat (*Triticum aestivum* L.) cultivar Sids 12 to nitrogen fertilizer rate under different planting methods. Each experiment included 12 treatments which were the combination between three nitrogen fertilizer rates (60, 80 and 100 kg Nitrogen/fad) and four planting methods with seed rate of 50 kg/fad. Planting methods included broadcasting (conventional tilled flat method), drill in rows (grains were drilled in a dig long narrow furrow 20 cm apart row), ridge (grain were drilled on three dig long narrow furrows on ridge (ridge side 60cm)) and bed (grain were drilled on six dig long narrow furrows on bed (bed side 120cm)). The experimental design was split plot design in 3 replications. The planting methods were arranged in the main plot and nitrogen fertilizers were allocated in the sub plots. The experimental unit area (plot area) was 14.4 m^2 (3.6×4 m).

Nitrogen fertilizer was applied as ammonium nitrate (33.5% N). The N fertilizer was added in two equal portions. The first portion was added just before the first irrigation, and the second portion was added just before the second irrigation. All recommended agronomic practices were uniformly applied to all of the experimental units.

Data recorded at harvest

At harvest, a sample one square meter of plants was collected at random and the following data were recorded: Plant height (cm), spikes no/ m^2, main spike length (cm), spike weight (g/main spike), grains No/main spike, grain yield (kg/ fad), straw yield (kg/fad), biological yield (kg/ fad), harvest index (HI) = grain yield (kg/fad) x 100/biological yield (kg/fad) test weight (g/l), 1000 grain weight (g) and vitreosness %. About 50 g of grain yield in three replications were fine grinding to determine nitrogen (N) percentage using microKjeldal method according to AOAC (1995). The crude protein content (GCPC) was calculated by multiplying total N% by 5.7. The grain crude protein yield (GCPY) was calculated by multiplying grain yield by grain crude protein content (GCPC).

Wet and dry gluten were determined according to the standard method of Pleshkov (1978) as the fine air dried grains by hand-washing the meal until starch was not detected in the washing water, then dried and weighed. Wet and dry gluten were calculated as percentage of air dry grains. The hydration capacity of gluten was calculated as follows: Hydration percentage = (wet gluten – dry gluten) x 100/dry gluten. The mechanical and chemical analyses of the experimental soil were estimated according to Black (1965) and Jackson (1967). Mechanical and chemical analysis of the experimental soil are presented in Table 1.

TABLE 1. Soil mechanical and chemical analysis of the experimental farm during 2013/2014 and 2014/2015 seasons.

Mechanical analysis	Average	Chemical analysis	Average
Sand %	16	pH	7.3
Silt %	29		
Clay %	55	EC (mmhos/cm)	1.1
		Organic Mater %	1.81
Soil texture	Clay loam	Nutrients(mg/kg soil)	
		Total N	1200
		P	95
		K	12.7

Statistical analysis

The obtained data were computed for proper statistical analysis according to SAS Program (2003). The LSR at 5% level of significance was used to differentiate between means. Data of 2013/2014 and 2014/2015 growing seasons were subjected to homogeneity variance test for running the combined analysis of the data.

Results and Discussion

Effect of nitrogen fertilizers

Data in Table 2 showed that yield components of wheat were significantly affected by nitrogen rates. Plant height (cm), spikes number/m^2, main spike length, main spike weight and grains number per main spike of wheat were markedly varied being in increasing order with different nitrogen rates 60, 80 and 100 kg N/fad. The application of 100 kg N/fad scored the maximum values of plant height (118.83 cm), spikes number/m^2 (655.17), main spike length (13.09 cm), main spike weight (5.54 g) and grains numbers per main spike (69.33). The significant enhancement of yield components in increasing order with different nitrogen rates can be credited to higher dose of nitrogen, which greatly helps the plant to expose its potential to grow potentially. These results are coincided with those reported by Podolska (2014) and Shukra et al. (2016).

TABLE 2. Yield components of wheat plant at harvest as affected by nitrogen fertilizer (combined data).

Nitrogen fertilizer kg N/fad	Plant height (cm)	Number of spikes /m^2	Main spike		
			length (cm)	Spike weight (g)	Number of grains
60	78.00c	279.17c	9.15c	4.03c	55.33c
80	107.33b	596.92b	12.00b	5.16b	66.08b
100	118.83a	655.17a	13.09a	5.54a	69.33a

Nitrogen levels effected significantly on grain yield. Data in Table 3 indicated that application of 100 kg N/fad was characterized by significant highest yield attributes, which reflected its yield parameters and produced significant maximum grain yield (3421.6 kg/fad) followed by 80 kg N/fad (3158.0 kg/fad) and 60 kg N/fad (2574.9 kg/fad). The highest grain yield of wheat can be attributed to more spikes number, weight and weight of grains per main spike due to higher fertilizer application (Table 2). These results are in accordance with those of Podolska (2014) and Shukra et al. (2016). The straw yield was subsequently and significantly affected by different nitrogen levels. 60, 80 and 100 kg N/fad were in increasing relationship with straw yield being 4187.3, 4949.0 and 5235.9 kg/fad, respectively. These results are similar with Shukra et al. (2016). From the above mentioned data in Tables 2 and 3, it could be concluded that the higher yield attributes, the higher grain and straw yields and subsequently the higher the biological yield. GCPY was significantly affected by different nitrogen levels. 100 kg N/fad applied nitrogen produced the highest GCPY (435.46 kg/fad) followed by 80 kg N/fad (390.27 kg/fad) and 60 kg N/fad (287.76 kg/fad). These results similar to results of Campillo et al. (2010). Harvest index was affected by nitrogen levels, 100 kg applied nitrogen produced the maximum harvest index (39.53 %).

TABLE 3. Wheat yield (kg/fad) and harvest indices (%) as affected by nitrogen fertilizer (combined data).

Nitrogen fertilizer kg N/fad	Yield (kg/fad)				Harvest index (%)
	Grain	Straw	Biological	Grain crude protein	
60	2574.9c	4187.3c	6762.3c	287.76c	38.06c
80	3158.0b	4949.0b	8090.4b	390.27b	38.77b
100	3421.6a	5235.9a	8657.5a	435.46a	39.53a

Table 4 showed that the studied nitrogen levels affected significantly on quality properties. 100 kg N applied scored the maximal test weight, thousand grain weight, vitreosness, wet and dry gluten exhibiting 848.88 g/l, 47.55 g, 46.38 %, 29.20 and 11.30 %, respectively, Agapie et al. (2016) reported similar results. A slight difference was noticed between 100 and 80 kg N/fad in thousand grain weight. On the other hand, hydration was slightly affected by different nitrogen levels ranging between 158.41 up to 173.81%.

TABLE 4. Effect of nitrogen fertilizer rates on some technological characters of wheat grain (combined data).

Nitrogen fertilizer kg N/fad	Test weight (g)	1000-grain weight (g)	Vitreo-sness %	Gluten (%)		Hydration %
				Wet	Dry	
60	791.50c	42.14b	36.25c	25.41c	9.28c	173.81a
80	836.50b	46.29a	44.69b	27.61b	10.21b	170.42a
100	848.88a	47.55a	46.38a	29.20a	11.30a	158.41a

Effect of planting methods

The planting methods showed remarkable effect on yield components of wheat plants including plant height, spikes No/m^2, main spike length and weight as well as grain No/main spike (Table 5). Number of grains/main spike is an important trait and has a direct effect on the final grain yield of wheat. Data revealed that planting methods affected significantly number of grains/main spike. Maximum number of grains/main spike was obtained when crop was sown on raised bed (68.33 grain/main spike) versus the minimal value in case of sowing broadcasting (58.78 grain/main spike). In addition, in all studied parameters were the highest due to sowing on raised bed than other different planting methods. It could be concluded that maximal yield components were obtained when wheat plants were sown on raised bed. This in agreement with Khaleque et al. (2008), Mollah et al. (2009), Kilic (2010) and Mollah et al. (2015).

The effects of planting methods on each of grain, straw, biological and grain crude protein (GCP) yields as well as harvest indices are presented in Table 6. Grain, straw and biological yields were at the maximal values when wheat plants sowing on raised bed being 3334.0, 5175.6 and 8487.4 kg/fad, respectively. Sowing wheat plant with others planting methods reduced grain, straw and biological yields. Grain was reduced by a rate of 20.62% when wheat plant sowing with broadcasting. Higher grain yield was obtained when crop was sown on raised bed and can be attributed to more number of spikes/m^2 and number of grains/main spike. These results agreed with early findings by Hossain et al. (2006), Khaleque et al. (2008), Mollah et al. (2009), Kilic (2010) and Mollah et al. (2015). While, maximal value of harvest index was obtained when wheat plants sowing on ridge being 39.18%. On the other hand, the GCP yield was slightly affected ranging between 353.63 to 386.39 kg/fad.

TABLE 5. Yield components of wheat plants as affected by planting methods (combined data).

Planting method	Plant height (cm)	Number of spikes/m^2	Main spike		
			length (cm)	Spike wt. (g)	Number of grains
Broadcasting	96.56c	531.44d	10.50d	4.39c	58.78c
Drill in rows	100.56b	545.56c	10.83c	4.62c	62.22bc
Drill on ridge	109.44a	607.78b	11.93b	5.09b	65.00ab
Drill on bed	111.00a	623.65a	12.39a	5.54a	68.33a

TABLE 6. Wheat yields (kg/fad) and harvest indices (%) of wheat plants as affected by planting methods (combined data).

Planting method	Yield (kg/fad)				Harvest index (%)
	Grain	Straw	Biological	Grain crude protein	
Broadcasting	2764.1d	4434.3b	7198.4d	353.63a	3826b
Drill in rows	2917.1c	4608.4c	7525.6c	365.19a	3878ab
Drill on ridge	3190.8b	4944.7b	8135.4b	386.39a	3918a
Drill on bed	3334.0a	5175.6a	8487.4a	379.45a	3896a

Data in Table 7 cleared that test weight and thousand grain weight were at the maximal values when wheat plants sowed on raised bed, being 841.50 g/l and 47.09 g, respectively. On other hand vitreosness, wet and dry gluten were at the highest values when wheat plants sowed broadcasting being 44.75, 30.22 and 11.15%, respectively. The effect of planting methods on grain quality was agree with Mollah et al. (2009) and Mollah et al. (2015).

TABLE 7. Effect of planting methods on some technological characters of wheat grain (combined data).

Planting method	Test weight (g/l)	1000-grain weight (g)	Vitreo-sness %	Gluten (%)		Gluten hydration %
				Wet	Dry	
Broadcasting	809.17c	43.20c	44.75a	30.22a	11.15a	171.95a
Drill in rows	816.00bc	44.77bc	43.00ab	28.67a	10.60ab	170.99a
Drill on ridge	835.83ab	46.26ab	41.33ab	26.18b	9.88bc	164.89a
Drill on bed	841.50a	47.09a	40.67b	24.57b	9.42c	160.83a

Effect of the interaction between nitrogen fertilizers and planting methods

The interaction between planting methods and nitrogen fertilizers affected significantly on yield components of wheat. The data in Table 8 cleared that application of 100 kg N/fad exhibited maximum tallest plants, spikes No/plant and main spike length with sowing wheat plants on raised bed or on ridge. Meanwhile, the application of 80 kg N/fad exhibited maximum values of weight/main spike (6.08 g) and grains No/main spike (72.33 grains/main spike) with sowing wheat plants on raised bed, similar with Yildirim et al. (2016).

TABLE 8. Effect of the interaction between nitrogen fertilizer and planting method on yield components (combined data).

Planting method	Nitrogen fertilizer kg N/fad	Plant height (cm)	Number of spikes/ m^2	Main spike		
				Length (cm)	Spike wt (g)	Number of grains
Broadcasting	60	78.00f	411.00h	7.60f	3.34e	47.67e
	80	98.33d	553.33e	11.00d	4.70cd	61.67cd
	100	113.33b	630.00bc	12.87ab	5.11bc	67.00abc
Drill in rows	60	82.33f	427.33g	7.90f	3.78e	53.33e
	80	104.33c	569.33d	11.60c	4.81bcd	65.33bcd
	100	115.00b	640.00b	13.00a	5.28b	68.00ab
Drill on ridge	60	92.33e	526.33f	10.13e	4.41d	59.67d
	80	112.67b	625.00c	12.50b	5.03bc	65.00bcd
	100	123.33a	672.00a	13.17a	5.83a	70.33ab
Drill on bed	60	95.33de	552.00e	10.97d	4.60cd	60.67d
	80	114.00b	640.00b	12.87ab	6.08a	72.33a
	100	123.67a	678.67a	13.33a	5.95a	72.00a

The high performance of wheat plants with 80 or 100 kg N/fad application and sowing plants on raised bed in yield attributes was reflected on its yield parameters (Table 9). The data cleared that grain yield was at the maximal values (3604.0 kg/fad) when wheat plants sowed on raised bed and application of 80 kg N/fad. While maximal values of straw (5475.3 kg/fad) and biological yields (9038.0 kg/fad) were obtained when wheat plants sowed on raised bed and application of 100 kg N/fad. The slightly different between application of 80 and 100 kg N/fad when wheat plants sowed on raised bed on all yield parameters. These finding are in good agreement with that obtained by Yildirim et al. (2016). On the other hand, GCP yield exhibited highest value (440.31 kg/fad) when wheat plants sowed on ridge and application of 100 kg N/fad. While the maximal value of harvest index (40.10%) was obtained when wheat plants sowed on broadcasting and application of 100 kg N/fad.

The interaction between nitrogen fertilizers and planting methods on technological characters are shown in Table 10. Data showed that application of 100 kg N/fad exhibited the highest values of test weight (863.00 g/l) on ridge, 1000-grain weight (48.60 g) on raised bed and dry gluten (12.40%) on broadcasting. Vitreosness, wet gluten and gluten hydration were slightly affected by interaction between nitrogen fertilizers and sowing methods.

From the above mentioned data, the author recommended that sowing wheat plants on raised bed was the best sowing method with application of 80 kg N/fad and can be tolerated the environmental conditions of Egypt.

TABLE 9. Effect of the interaction between nitrogen fertilizer and planting method on yield (kg/fad) and harvest indices (HI,%) (combined data).

Planting method	Nitrogen fertilizer kg N/fad	Yield (kg/fad)				Harvest index %
		Grain	Straw	Biological	Grain crude protein	
Broadcasting	60	2233.7g	3760.7h	5994.3i	261.01e	37.26f
	80	2767.7e	4627.3e	7395.0f	358.11c	37.42ef
	100	3291.0c	4915.0c	8206.0d	441.77a	40.10a
Drill in rows	60	2463.3f	3908.7g	6372.0h	279.41de	38.65cd
	80	2950.7d	4775.0d	7725.7e	376.74bc	38.10de
	100	3337.3c	5141.7b	8479.0c	439.42a	39.36abc
Drill on ridge	60	2767.3e	4447.7f	7215.0g	307.59d	38.36d
	80	3309.7c	4974.7c	8284.3d	411.26ab	39.95ab
	100	3495.3b	5411.7a	8907.0b	440.31a	39.24bc
Drill on bed	60	2835.3e	4632.3e	7267.7f	303.03d	37.97def
	80	3604.0a	5419.0a	9023.0ab	414.97ab	39.50abc
	100	3562.7ab	5475.3a	9038.0a	420.36a	39.42abc

TABLE 10. Effect of the interaction between nitrogen fertilizer and planting method on some technological characters of wheat grains (combined data).

Planting method	Nitrogen fertilizer kg N/fad	Test weight (g/l)	1000-grain weight (g)	Vitreo-sness %	Gluten (%)		Gluten hydration %
					Wet	Dry	
Broadcasting	60	775.00f	38.51e	39.00a	28.15a	10.05cdef	180.10a
	80	820.00cd	44.78bc	46.50a	30.30a	11.00bc	175.45a
	100	832.50bcd	46.30abc	48.75a	32.20a	12.40a	159.68a
Drill in rows	60	780.50af	40.99de	36.50a	27.10a	9.70def	179.38a
	80	827.50cd	45.75abc	45.50a	28.10a	10.55bcd	166.35a
	100	840.00abc	47.56abc	47.00a	30.80a	11.55ab	166.67a
Drill on ridge	60	804.05def	43.97cd	35.50a	24.20a	9.20fg	163.04a
	80	840.00abc	47.05abc	43.50a	26.80a	9.95cdef	169.35a
	100	863.00a	47.75ab	45.00a	27.55a	10.50bcde	162.38a
Drill on bed	60	806.50de	45.09abc	34.00a	22.20a	8.15g	172.39a
	80	858.50ab	47.58ab	43.25a	25.25a	9.35ef	170.05a
	100	860.00ab	48.60a	44.75a	26.25a	10.75bcd	144.19a

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استجابة محصول القمح ومكوناته والخصائص التكنولوجية لطرق زراعة مختلفة و معدلات من التسميد النيتروجينى

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أقيمت تجربتان حقليتان فى محطة التجارب الزراعية التابعة لكلية الزراعة جامعة عين شمس – شلقان- محافظة القليوبية خلال موسمى الزراعة 2013/2014 و 2014/2015 لدراسة استجابة قمح الخبز للتسميد النيتروجينى تحت طرق زراعة مختلفة. اشتملت كل تجربة على 12 معاملة والتى كانت عبارة عن التألف بين ثلاثة معدلات من التسميد النيتروجينى (60، 80 و100كجم نيتروجين/ فدان) وأربعة طرق زراعة (بدار، تسطير، على خطوط و الزراعة على مصاطب) فى تصميم تجريبى قطعة منشقة مرة واحدة فى ثلاث مكرارات. أشارت النتائج إلى أن معدل التسميد 100كجم نيتروجين/ فدان سجل زيادة معنوية فى مكونات المحصول مما انعكس على محصول الحبوب النهائى 3421.6كجم حبوب /فدان يلية 80كجم نيتروجين/فدان (3158.0كجم حبوب/فدان) ثم 60كجم نيتروجين/فدان(2574.9كجم حبوب/فدان). سجلت اعلى قيم وزن الهكتوليتر (جم/لتر)، وزن1000حبة (جم)، ٪الشفافية و ٪ للجلوتين الرطب والجاف عند تسميد القمح بـ 100كجم نيتروجين/فدان. أظهرت الزراعة على المصاطب اعلى قيمة لعدد الحبوب بالسنبلة الرئيسية (68,33 حبة/سنبلة) مقارنة بأقل قيمة عدد الحبوب للسنبلة الرئيسية عند الزراعة البدار. كما حققت الزراعة على المصاطب اعلى القيم فى جميع الصفات المحصولية المدروسة مقارنة بطرق الزراعة الأخرى، حيث سجلت اعلى قيم لمحصول الحبوب (3334.0كجم حبوب/ فدان), القش (5175.6كجم/فدان) والبيولوجى (8487.4كجم/فدان)، من ناحية اخرى سجلت الزراعة البدار اعلى القيم فى ٪ للشفافية والجلوتين الرطب والجاف. بينما وجد ان التسميد بـ 80كجم نيتروجين/فدان يعطى اعلى القيم لعدد الحبوب بالسنبلة الرئيسية (72.33 حبة/سنبلة) واعلى محصول حبوب للفدان (3604.0 كجم حبوب/ فدان) عند الزراعة على المصاطب. كما أحدث التفاعل بين كلاً من طرق الزراعة ومستويات التسميد النيتروجينى أختلافات معنوية فى وزن الهكتوليتر, وزن الـ 1000حبة و٪ للجلوتين الجاف.