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Variation of Some Yield–contributing Traits of Winter Wheat (*Triticum aestivum* L.) Varieties under the Effect of Furolan and Mineral Fertilizer

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Authors' contributions

This work was carried out in collaboration between all authors. Authors EO and VZ designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EO, HEE and VZ managed the analyses of the study. Author VZ managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study was carried out to investigate the variation of some yield contributing traits namely; grain weight ear^{-1}, grain weight plant^{-1}and 1000–grain weight in three winter varieties under the influence of the following factors including;, growth regulator, Furolan and mineral fertilizer.
Sample: Three winter varieties used for this study were subjected to the following factors namely; mineral fertilizers and growth regulator, Furolan.
Study Design: The seeds were planted in 3 m x 8 m = 24 m^2 plot of in three replicates in complete randomized design.

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Place and Duration of Study: The laboratory tests and field work were carried out in the All-Russian Rice Research Institute, Belozerny, Krasnodar, Russia from 2009 to 2011.
Methodology: The laboratory tests and field work were carried out in All-Russian Rice Research Institute, Belozerny, Krasnodar, Russia from 2009 to 2011. The variation of some yield-contributing traits in three winter varieties under the influence of mineral fertilizers and growth regulator, Furolan was investigated. The data obtained from this factorial experiment were subjected to analysis of variance (ANOVA).
Results: For the factor A (variety) grain weight ear^{-1} of varieties studied varied as follows: 1.17 g (Deya); 1.19 g (Krasnodarskaya 99) and 1.25 g (Bat'ko), (LSD_{05}-factor A = 0.01). The best performing variety on the account of this trait under the influence of mineral fertilizers and growth regulator was Bat'ko (variety) which formed grain weight ear^{-1} of 1.25 g.
Conclusion: From this study; investigating the effect of Furolan and mineral fertilizers on some of the yield-contributing traits in three winter wheat varieties it might be concluded that the yield performance in various yield traits was generally enhanced under the influence of these factors particularly when they were combined. The information generated from this study could be used to identify effective strategies for the sustainable management of the genetic resources of wheat.

Keywords: Furolan; mineral fertilizer; wheat varieties; yield–contributing traits.

1. INTRODUCTION

Wheat (*Triticum* spp.) [1–3] is a cereal grain, originally from the Levant region of the Near East and Ethiopian Highlands, but now cultivated worldwide. In 2010, world production of wheat was 651 million tons, making it the third most-produced cereal after maize (844 million tons) and rice (672 million tons) [4,5]. Globally, wheat is the leading source of vegetable protein in human food, having a higher protein content than other major cereals, maize (corn) or rice [6–8]. In terms of total production tonnages used for food, it is currently second to rice as the main human food crop and ahead of maize, after allowing for maize's more extensive use in animal feeds.

Technological advances in soil preparation and seed placement at planting time, use of crop rotation and fertilizers to improve plant growth, and advances in harvesting methods have all combined to promote wheat as a viable crop. Yields of pure wheat per unit area increased as methods of crop rotation were applied to long cultivated land, and the use of fertilizers became widespread. Improved agricultural husbandry has more recently included threshing machines and reaping machines (the 'combine harvester'), tractor-drawn cultivators and planters, and better varieties (Einkorn, Common wheat or Bread wheat, Spelt, Norin 10 wheat etc.) [9,10].

The mass of 1,000 grains or thousand kernels weight (TKW) is the weight of air-dried and undamaged grains. It is used as one of the parameters for assessing the quality of grain. Grains with higher TKW have better milling quality and ensure better emergence. The mass of 1,000 grains as a final component of grain yield depends on many components that develop in the previous phases of ontogenesis.

Because there is an over-production of most plant organs in each phase of wheat plant growth, it is possible that mass of 1,000 grains could be influenced by agro-ecological conditions and agro-technical measures such as date and quality of sowing, mineral fertilizers and irrigation. TKW depends on the variety and varies widely [11,12]. Unfavourable conditions during the growth of wheat plant can be partly compensated by creating favourable conditions that will increase mass of 1,000 grains [13,14].

A strong positive correlation of top leaf area, internodes and spike with grain mass was proven by [15] who concluded that the selection for these traits will increase yield. In agroecological conditions of Serbia and in varieties cultivated there, the mass of 1,000 grains ranged from 33-45 g, 38 g on average [16,17].

Furolan, the growth regulator used in this study was created by KubSUT (Kuban State University of Technology) [18]. The name of the active substance of Furolan according to ISO is – 2-(1, 3-dioksolanyl-2) furan and by IUPAC – (2-furil)-1, 3–dioksolan. Furolan–is a colorless liquid with weak characteristic acetylene smell, containing 98.89% of active substance, 2 (1, 3 dioksolanyl-2) furan, soluble in water and adequately soluble in organic solvents. Furolan shows antistress activity and is permitted for use in Russia on a variety of agricultural crops, including wheat [19–21]. Furolan is classified with median lethal dose (LD50) of 511–626 mg/kg).

The objective of the present study is to investigate variation of some yield contributing traits namely; grain weight ear^{-1}, grain weight plant^{-1}and 1000–grain weight in three winter varieties under the influence of the following factors including; growth regulator, Furolan and mineral fertilizer. This would help in improving the different wheat genotypes being cultivated and further determine the most suitable and favourable conditions for the cultivation of these varieties. The information generated from this study could be used to identify effective strategies for the sustainable management of the genetic resources of wheat.

2. MATERIALS AND METHODS

The laboratory tests and field work were carried out in All-Russian Rice Research Institute, Belozerny, Krasnodar, Russia from 2009 to 2011. The variation of the following yield-contributing traits; grain weight ear^{-1}, grain weight plant^{-1} and 1000–grain weight in three winter varieties namely Batko, Deya and Krasnodarskaya 99 under the influence of the following factors namely; mineral fertilizers and Furolan was investigated.

Treatment of fertilizers was carried out according to the following scheme: $N_{50}P_{90}K_{40}$ was used for the basic soil treatment plus N_{60} – for top-dressing during spring and then N_{30} − for foliar top-dressing during the ear formation phase. Thereafter, the wheat varieties were sprayed at the elongation phase with a dose of 5 g/hectare of Furolan (growth regulator) mixed in water solution using a dosimeter.

The treated variants of the winter wheat varieties were sown at the end of September in three replicates in an experimental plot of 3 m x 8 m = 24 m^2. The plots were completely randomized. About 5 million grains of all the varieties studied were sown per hectare.

After the harvesting, the grains of each variant and replicate were cleared of physical impurity and separated into portions for further analysis. Yield in terms of grain weight per plot was determined within the limits of average weight; 9 kg to 13 kg at the experimental condition of 14% grain humidity.

The data obtained from this factorial experiment were subjected to analysis of variance (ANOVA) using SPSS version 21.

3. RESULTS AND DISCUSSION

3.1 Grain Weight Ear^{-1}

The grain weight ear^{-1} is one of the basic traits which with high accuracy could determine winter wheat yield. Product of grain weight ear^{-1} and number of productive stalks per m^2 equals to yield. Also, grain yield can be expressed as the product of three variables (yield components): grain yield = (number of heads) x (kernels per head) x (kernel weight).

From data obtained in this factorial experiment the grain weight ear^{-1} of Batko variety varied from 1.19 g (control) to 1.31 g (mineral fertilizers + growth regulator). The difference between the variants at the extreme was 0.12 g. By application of only Furolan the grain weight ear^{-1} was 1.23 g; 0.04 g more than the control (LSD_{05}-variant = 0.01). Treatment of winter wheat plants with Furolan solution at harvest output phase showed significant increase of grain weight ear^{-1}. With application of only mineral fertilizers the grain weight ear^{-1} of Batko variety amounted to 1.27 g; 0.08 g more than control. Mineral fertilizers significantly increased the grain weight ear^{-1} (Table 1).

In the variant treated with mineral fertilizers and growth regulator the grain weight ear^{-1} obtained was 1.31 g; 0.12 g more than control (LSD_{05}-variant = 0.01). Similar pattern was observed with other treated variants.

For the factor A (variety) grain weight ear^{-1} of varieties studied varied in the following sequence: 1.17 g (Deya); 1.19 g (Krasnodarskaya 99) and 1.25 g (Bat'ko), (LSD_{05}-factor A = 0.01). The best performing variety on the account of this trait under the influence of mineral fertilizers and growth regulator was Bat'ko (variety) which formed grain weight ear^{-1} of 1.25 g.

For the factor B (mineral fertilizers) the grain weight ear^{-1} varied from 1.17 g (control) to 1.24 g (mineral fertilizers). The difference between these variants was 0.07 g (LSD_{05}-factor B = 0.02). Differences in grain weight ear^{-1} among the fertilized variants were significant.

Table 1. Data on variation of some yield–contributing traits of winter wheat varieties under the effect of Furolan and mineral fertilizer

Variety	Mineral fertilizers	Growth regulator	Grain weight (g) ear^{-1}							Grain weight (g) plant^{-1}							1000-grain weight (g)						
				Average for:							Average for:							Average for:					
			Variants	A	B	C	AB	AC	BC	Variants	A	B	C	AB	AC	BC	Variants	A	B	C	AB	AC	BC
Bat'ko	Control	Control	1.23					1.17	1.15	1.98						1.83	38.6		38.5		39.0		38.3
		Furolan	1.23		1.17		1.21	1.23	1.19	2.00		1.84		1.99	1.73	1.92	39.3					39.0	38.6
	$N_{50}P_{90}K_{40}$ + N_{60} in the spring + N_{30} at spike formation	Control	1.27	1.25					1.22	2.15	1.96					2.06	39.4	39.3	39.1		39.6		38.9
		Furolan	1.31		1.24		1.29		1.25	2.36		1.95		2.02	2.18	2.13	39.9					39.6	39.3
Deya	Control	Control	1.12					1.15		1.68							38.5				38.6		
		Furolan	1.16				1.14	1.18		1.86				1.77	1.79		38.7					38.7	
	$N_{50}P_{90}K_{40}$ + N_{60} in the spring+ N_{30} at spike formation	control	1.18	1.17						1.89	1.84						38.9	38.9			39.1		
		Furolan	1.20				1.19			1.92				1.91	1.89		39.3					39.0	
Krasnodar-skaya 99	Control	Control	1.14					1.17		1.82							37.8				37.9		
		Furolan	1.18			1.18	1.16	1.21		1.89				1.86	1.87		37.9			38.6		37.9	
	$N_{50}P_{90}K_{40}$ + N_{60} in the spring+ N_{30} at spike formation	Control	1.20	1.19						1.92	1.94		1.80				38.3	38.2			38.5		
		Furolan	1.25			1.18	1.23			2.12			2.03	2.02	2.00		38.6			38.9		38.5	
LSD_{05}			0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.59	0.30	0.24	0.24	0.42	0.42	0.34	0.15	0.08	0.06	0.06	0.11	0.11	0.09

"A", "B" and "C" respectively represent factors; A (Variety); B (mineral fertilizer) and C (growth regulator, Furolan).
"AB", "BC" and "AC" respectively represent interaction between factors; A and B; B and C; and A and C

For the factor C (growth regulator) the grain weight ear^{-1} on the average varied from 1.18 g (without treatment) to 1.22 g (treated with Furolan). The difference between these variants in grain weight ear^{-1} was 0.04 g (LSD_{05}-factor C = 0.01). Treatment of varieties of winter wheat plants with growth regulator, Furolan significantly increased grain weight ear^{-1}.

The results of interaction of factors A and B (AB) showed that the grain weight ear^{-1} of all winter wheat varieties with application of mineral fertilizers significantly increased as follows: by 0.08 g (Bat'ko); 0.05 g (Deya) and 0.07 g (Krasnodarskaya 99). The varieties studied responded moderately to mineral fertilizers during the formation of grain weight ear^{-1}. Accordingly they had the following respective response indices: 1.07; 1.04 and 1.06.

The result of interaction of factors A and C (AC) showed that the grain weight ear^{-1} in varieties on application of growth regulator, Furolan increased thus: 0.06 g (in Bat'ko); 0.03 (in Deya) and 0.04 g (in Krasnodarskaya 99). Application of growth regulator, Furolan significantly (LSD_{05}-interaction AC = 0.01) increased the grain weight ear^{-1}. However, the varieties investigated showed weak response to growth regulator during the formation of grain weight ear^{-1} with the following respective response indices: 1.05 (in Bat'ko); 1.03 (in Deya) and 1.03 (in Krasnodarskaya 99).

The results of the interaction of factors B and C (BC) showed that the grain weight ear^{-1} for the variants varied from 1.15 g (control) to 1.25 g (mineral fertilizers plus Furolan). In the integrated study of mineral fertilizers and growth regulator it was observed that Furolan increased the grain weight ear^{-1} by 0.04 g in comparison with control. With only mineral fertilizers the grain weight ear^{-1} increased on the average by 0.07 g in comparison with control. The variant with combined application of mineral fertilizers and Furolan increased grain weight ear^{-1} on the average by 0.1 g (LSD_{05}-interaction BC = 0.02). All increases with application of mineral fertilizers and growth regulator were statistically significant [22,23].

In our study the application of mineral fertilizers and growth regulator significantly increased the grain weight ear^{-1} in all the variants investigated.

By means of the three-factorial analysis of grain weight ear^{-1} trait, it was established that the influence of the general variation during its formation was 34.4%. The effect of treated variants was 31.3% while that of factor A (variety) was 15.6%. This influence of genotypes of varieties investigated during formation of grain weight ear^{-1} was moderate.

The influence of factor B (doses of mineral fertilizers) during grain weight ear^{-1} formation was 13.5%. The effect of mineral fertilizers in comparison to genotypes on varieties on the formation of grain weight ear^{-1} was similar. The effect of the factor C (growth regulator) during the formation of grain weight ear^{-1} at 5.1% was weak. However, Furolan influenced basically the size, maturity and 1000− grain weight. Thus, the total effect of different factors during the formation of grain weight ear^{-1} amounted to 65.6%. This effect is important and useful in improving yield in wheat plants.

3.2 Grains Weight Plant^{-1}

Grain weight plant^{-1} is an important yield-contributing trait of winter wheat varieties. It depends on the productive bushiness and grain weight ear^{-1} traits. These are highly correlated traits. The phenotypic correlation was estimated from the values of traits as follows: productive bushiness and grain weight ear^{-1} (r = 0.76); productive bushiness and grain weight plant^{-1} (r = 0.95).

The results of grain weight plant^{-1} in this factorial experiment revealed that in Bat'ko variety it varied from 1.98 g (control) to 2.36 g (mineral fertilizers and growth regulator). There was significant difference (LSD_{05}-variant = 0.59) between variants at the extreme of 0.38 g. The increase in grain weight plant^{-1} in winter wheat varieties under the influence of mineral fertilizers and growth regulator was insignificant but noticeable tendency to increase (in grain weight plant^{-1}) was observed (Table 1).

For factor A (variety) grain weight plant^{-1} varied in the following sequence: 1.84 g (Deya); 1.94 g (Krasnodarskaya 99) and 1.96 g (Bat'ko). In spite of the fact that between the varieties there were differences in grain weight plant^{-1}, but they were, however, insignificant (LSD_{05}-factor A = 0.30).

For factor B (mineral fertilizers) the grain weight plant^{-1} varied from 1.84 g (control) to 1.95 g (combined application of factors). The difference between variants in grain weight plant^{-1} of 0.11 g was insignificant (LSD_{05}-factor B = 0.24).

For factor C (growth regulator) the grain weight plant^{-1} varied from 1.80 g (without treatment) to 2.03 g (Furolan-treated). Difference in grain weight plant^{-1} between variants was 0.23. This was not significant and within the LSD limits. The growth regulator, Furolan showed stimulating effect during the formation of grain weight plant^{-1}.

The results of interaction of factors A and B (AB) showed that the fertilized variants increased grain weight plant^{-1} in winter wheat varieties. With application of mineral fertilizers grain weight plant^{-1} increased as follows: 0.03 g (Bat'ko); 0.14 g (Deya) and 0.16 g (Krasnodarskaya 99), (LSD_{05}-interaction AB = 0.42). The increase obtained in grain weight plant^{-1} in winter wheat varieties was statistically insignificant showing mineral fertilizers had stimulating effect.

Interaction of factors A and C showed that after the treatment of plants of winter wheat varieties with growth regulator, Furolan an increase in grain weight plant^{-1} in comparison with control was observed. Only Bat'ko variety showed significant increase in grain weight plant^{-1} in comparison with control. The difference between the variants was 0.45g (LSD_{05}-interaction AC = 0.42). Other varieties showed insignificant increase in grain weight plant^{-1} in comparison with control. The increase in Bat'ko variety of grain weight plant^{-1} was significant. This could be explained as a good response to mineral fertilizers during the formation of grain weight plant^{-1} of 1.26.

The results of interaction of factors B and C showed that there was a tendency to increase in grain weight plant^{-1} under the influence of various doses of mineral fertilizers and growth regulator. The difference between variants at the extreme as result of the interaction B and C on grain weight plant^{-1} was 0.3 g (LSD_{05}-interaction BC = 0.34). Thus, the interaction of factors: mineral fertilizers and growth regulator caused increase in grain weight plant^{-1} although was statistically insignificant.

By means of the three-factorial analysis it was established that the influence of the general variation during the formation of grain weight plant^{-1} was 32.0%. The effect of variants was 25.9%. The effect of the factor A (variety) was 15.3%. The influence of genotypes of varieties on the productivity was on the average [24,25]. The influence of the factor B (doses of mineral fertilizers) during the formation of grain weight plant^{-1} was 15.0%. This was a significant effect on the formation of the quantity of trait. The effect of the factor C (growth regulator) on the formation of grain weight plant^{-1} was 10.7%. The growth regulator, Furolan was capable of increasing the size of grain and 1000–grain weight by 5.8 g.

3.3 1000– Grain Weight

The 1000–grain weight is another important yield-contributing trait of any variety representing its technological quality. It is a stable high-quality trait which is not seriously affected by ecological or modification variation [26]. Damage of plants by pests and diseases, drought conditions, dry winds at the ripening and maturity stages of grains, flooding of stalks, etc. leads to reduction of 1000–grain weight trait, causing weakening of grains. All these factors negatively impacted on 1000–grain weight trait. The trait is highly correlated with such characteristics as grain quantity ear^{-1} (r = 0.57), grain weight plant^{-1} (r = 0.79) and grain weight plant^{-1} (r = 0.77). Two traits are particularly, clearly highly correlated: 1000–grain weight and grain number ear^{-1} (r = 0.57) [26]. The determining factor (correlation coefficient squared) was equal to 0.32. This meant that the trait, 1000–grain weight and grain number ear^{-1} in 32% of cases were controlled by the genotype of varieties and in 68% of cases by ecological and external factors (Table 1).

The results of three-factorial analysis showed that 1000–grain weight in treated variants of Bat'ko variety varied from 38.6 g (control) to 39.9 g (mineral fertilizers and growth regulator). The difference between variants at the extreme was 1.3 g (LSD_{05}-var. = 0.15). Application of mineral fertilizers and growth regulator showed significant increase in the 1000–grain weight. With application of only growth regulator the 1000–grain weight in Bat'ko variety increased by 0.7 g (LSD_{05}-var. = 0.15). By application of only mineral fertilizers the 1000–grain weight formed was 39.4 g; 0.8 g more than control. By combined application (of mineral fertilizer and growth regulator) on this variant the 1000–grain weight formed was 39.9 g; 1.3 g more than the control. Similar trend was observed in other varieties. From these results, it could be observed that there was significant increase in 1000–grain weight in all treated variants with the application of mineral fertilizers and growth regulator. This means that in order to obtain mature and large seeds of winter wheat variety mineral fertilizers and growth regulator, Furolan should be expediently used on seed crops.

The analysis of results of interaction of factors A and B on 1000–grain weight showed that in Bat'ko variety it varied from 39.0 g (control) to 39.6 g (variant with mineral fertilizers). By application of mineral fertilizers the 1000–grain weight increased by 0.6 g in comparison with control (LSD_{05}-interact. AB = 0.11). Statistically significant increase of 1000–grain weight in Bat'ko variety with application of mineral fertilizers was observed.

In Deya's variety, by the interaction of factors A and B significant increase in 1000–grain weight of 0.5g was obtained. In Krasnodarskaya 99 1000–grain weight increased by 0.6 g after application of mineral fertilizers. Thus, interaction of factors A and B showed significant increase in 1000–grain weight in all varieties of winter wheat.

The analysis of results of interaction of factors A and C during the formation of 1000–grain weight showed that it was significantly increased in all varieties of winter wheat by application of Furolan during cultivation of seeds. In Bat'ko variety by application of Furolan the 1000–grain weight increased by 0.6 g (LSD_{05}-interact. AC = 0.11). In other varieties significant increase in 1000–grain weight was also obtained. The growth regulator, Furolan had significant effect leading to the enlargement and largeness of winter wheat seeds. It was expedient to apply it (Furolan) on winter wheat during the controlled production of their seeds.

The effect of interaction of factors B and C showed significant increase in 1000–grain weight on the average in all the treated variants.

By means of the three-factorial analysis it was observed that the influence the general variation on 1000–grain weight was 34.4%. The effect of treated variants amounted to 30.8%. The effect of the factor A (variety) was 15.1% which invariably was the average value of the genotypic effect on 1000–grain weight. This was a confirmation that 1000–grain weight related more to high-quality trait than to ecological predisposition.

The influence of the factor B (mineral fertilizers) on the formation of 1000–grain weight was 14.6%. This goes to buttress the fact that mineral fertilizers throughout all the stages of organogenesis and subsequent ripening and formation of seeds play significant role in the cultivation of winter wheat varieties. The effect of factor C (growth regulator) on 1000–grain weight formed was 5.0%. This supports the fact that Furolan influenced the process of the formation of grains of winter wheat varieties at the last stages organogenesis.

4. CONCLUSION

It was observed in this study, that the yield performance in various yield traits was generally enhanced under the influence of these factors particularly more so when they were combined. The outcome of this study, could be further explored in future in the formulation of strategy and plans for improvement in cultivation of wheat.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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