Volume 21(4), 120- 124, 2017
JOURNAL of Horticulture, Forestry and Biotechnology
www.journal-hfb.usab-tm.ro

Effect of soil works and fertilisation on yield in winter two-row barley

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Abstract To get high yields in winter two-row barley, we need to observe all cultivation technology steps. This means high-quality soil works and all other works during crop vegetation. Preparing the soil for the sowing of winter two-row barley has always risen issues because of the short period between the harvesting of the pre-emergent crop and sowing, and of unfavourable weather conditions during soil preparation for sowing (8). Soil works are meant to focus on aerating the soil, on accumulating water and on establishing soil water balance (10). In winter two-row barley, they recommend mineral fertilisers (mainly phosphorus and phosphate one) that enhance starch content and, hence, grain quality (11). Soil works and fertilisation had significant influence on yield in winter two-row barley in 2015. The three variants of soil preparation allowed yield between 61.08 q/ha when using scarification + disking (2x) and 63.18 q/ha when using ploughing + disking (2x). When using ploughing + disking, fertilisation determined a variation of the yield of 3.54 q/ha. When using two diskings, fertilisation generated a yield span of 2,193 kg/ha varying between 4,780 kg/ha in the control variant and 6,973 kg/ha in the variant $N_{90}P_{90}K_{60}$. Different combinations of macro elements allowed yields between 48.03 q/ha in the control variant and 70.54 q/ha in the variant $N_{90}P_{90}K_{60}$, with medium variability (10.24%).

Key words

winter two row-barley, soil works, fertilisation, yield

Soil works are of particular importance in agriculture because they ensure proper life conditions for the crops, from sowing to harvesting (9).

Soil works are the main step in cropping because they act on the physical, chemical, biological and fertility features of the soil. The need to cultivate as many crops as possible in different climate and soil areas has contributed to the development and improvement of soil works; however, in numerous cases, this activity has become excessive (in numbers, intensity, timing, type of agricultural machines, etc.), which has a negative impact on soil features (1, 2, 3, 7).

Fertilisation means applying fertilisers to increase soil or soil layer fertility and, implicitly, crop yield (6).

Nitrogen, used at too high rates, weakens crop resistance to fall and diseases and, in winter two-row barley, frost resistance (5).

Phosphorus influences crop maturation, grain size and evenness, and starch content (12).

Potassium participates in the synthesis of organic matter in the plant; it increases crop resistance to frost, drought, fall and disease, thus determining yield quality.

Material and Method

The trial was a bifactorial one, of the 3 x 12 type, with 36 trial plots.

The experimental factors were:

- **Factor A – soil works, with the following graduations:** a_1 – ploughing + GD 5; a_2 – GD 5 (2X); a_3 – scarification + GD 5;
- **Factor B – fertilisation, with the following graduations:** b_1 – $N_0P_0K_0$; b_2 – $N_0P_{60}K_0$; b_3 – $N_0P_0K_{60}$; b_4 – $N_{60}P_0K_0$; b_5 – $N_{60}P_{60}K_{60}$; b_6 – $N_{60}P_0K_{60}$; b_7 – $N_0P_{60}K_{60}$; b_8 – $N_{60}P_{60}K_{60}$; b_9 – $N_{90}P_{60}K_{60}$; b_{10} – $N_{90}P_0K_{60}$; b_{11} – $N_{90}P_{60}K_0$; b_{12}- $N_{90}P_{90}K_{60}$.

The winter two-row barley cultivar used was SALAMANDRE, of French origin.

Results and Discussions

Taking into account the data presented in Table 1 below, we see that the two variation sources (soil works and fertilisation) had significant influences on yield in winter two-row barley in 2015. Fertilisation had a higher influence (48.35%) than oil preparation (32.82%). We can also see that the interaction between soil works and fertilisation had considerable statistically ensured influences (8.64%) on yield. The cumulated effect of these variation sources on yield in 2015 was 92.66%.

Table 1

Variance analysis regarding the effect of soil works and fertilisation on yield in winter two-row barley (2015)

Variation source	SP	GL	S^2	F test
Total	10386.61	107		
Replicates	10.25	2	5.13	1.15
Soil work	70.56	2	35.28	7.93**
Soil work error	17.80	4	4.45	
Fertilisation	9016.08	11	819.64	12.27**
Soil works x Fertilisation	536.84	22	24.40	2.19**
Fertilisation error	735.08	66	11.14	

In all three trial soil preparation variants, yield ranged between 61.08 q/ha when using scarification + disking (2x) and 63.18 q/ha when using ploughing + disking (2x), with low variability (1.70%) between soil works (Table 2). Though, overall, the variant ploughing + disking (2x) allowed yield increases of 1-3%, only the difference between it and the variant scarification + disking (2x) was statistically ensured.

Table 2

Yield in winter two-row barley with different soil works (2015)

Soil works	Yield (q/ha)		Relative values (%)	Difference/Significance
$A_2 – A_1$	62.28	63.18	98.58	-0.90
$A_3 – A_1$	61.08	63.18	96.68	-2.10^{0}
$A_3 – A_2$	61.08	62.28	98.07	-1.20

$DL_{5\%}$ = 1.38 q/ha, $DL_{1\%}$ = 2.29 q/ha, $DL_{0.1\%}$ = 4.28 q/ha

A_1 – Ploughing + Disking (2x); A_2 – Disking (2 x); A_3 – Scarification + Disking (2x)

As for the effect of fertilisation on yield in winter two-row barley in 2015, Table 3 below shows that different types of combinations of macro elements allowed yields ranging between 48.03 q/ha in the control variant and 70.54 q/ha in the variant $N_{90}P_{90}K_{60}$, with medium variability (10.24%).

Table 3

Yield in winter two-row barley with different types of fertilisation (2015)

Fertilisation type	Yield (q/ha)	Compared to $N_0P_0K_0$		Compared to the mean	
		Relative value (%)	Difference/ Significance	Relative value (%)	Difference/ Significance
$N_0P_0K_0$	48.03 e	100	Control	77.24	-14.15^{000}
$N_0P_{60}K_0$	58.86 c	122.55	10.83***	94.66	-3.32^{0}
$N_0P_0K_{60}$	55.49 d	115.53	7.46***	89.24	-6.69^{000}
$N_{60}P_0K_0$	60.33 c	125.61	12.30***	97.02	-1.85
$N_{60}P_{60}K_0$	61.59 c	128.23	13.56***	99.05	-0.59
$N_{60}P_0K_{60}$	60.38 c	125.71	12.35***	97.10	-1.80
$N_0P_{60}K_{60}$	61.52 c	128.09	13.49***	98.94	-0.66
$N_{60}P_{60}K_{60}$	65.34 b	136.04	17.31***	105.08	3.16*
$N_{90}P_{60}K_{60}$	68.30 ab	142.20	20.27***	109.84	6.12***
$N_{90}P_0K_{60}$	67.62 ab	140.79	19.59***	108.75	5.44***
$N_{90}P_{60}K_0$	68.17 ab	141.93	20.14***	109.63	5.99***
$N_{90}P_{90}K_{60}$	70.54 a	146.87	22.51***	113.44	8.36***
Trial mean	62.18	129.46	14.15***	100	Control

- $DL_{5\%}$ = 3.14 q/ha, $DL_{1\%}$ = 4.17 q/ha, $DL_{0.1\%}$ = 5.42 q/ha

Compared to the control variant (Table 3), we see that fertilisation with macro elements had a significant effect on yield in winter two-row barley in 2015, determining very significant increases ranging between 15.53% in the variant $N_0P_0K_{60}$ and 46.87% in the variant $N_{90}P_{90}K_{60}$. We also see that yield increases were progressive and somehow proportional with the amount of active substance applied.

Unilateral nitrogen fertilisation had a significantly higher effect on yield: 0.43%/kg a.s. compared to the effect of unilateral phosphorus (0.38% per kg a.s.) and potassium (0.26% per kg a.s.)

fertilisation. When applying 120 kg a.s., yield increases per kg a.s. ranged between 0.21% and 0.23%. In the variants treated with over 180 kg a.s., the highest yield increase of 0.27-0.28% per kg a.s. was in the variants $N_{90}P_{60}K_{60}$ and $N_{90}P_{60}K_{0}$.

Taking into account mutual comparisons between fertilisation types from the perspective of yield, we see that the variants treated with over 180 kg a.s. per ha had a significantly superior efficacy materialised in yield increases of over 603 kg/ha. Unilateral application of only 60 kg of potassium had a lower efficacy determining a significant lower yield than unilateral fertilisation with nitrogen and phosphorus or with both of them.

Compared to the trial mean, we noted four variants in particular: $N_{90}P_{90}K_{60}$, $N_{90}P_{60}K_{60}$, $N_{90}P_{60}K_{0}$ and $N_{90}P_{0}K_{60}$, that had a superior efficacy materialised in yield increases ranging between 544 and 836 kg/ha.

In the control variant and in the variants treated unilaterally with phosphorus and potassium, yield was significantly inferior to the mean (3.32-14.15 q/ha). In the other variants, yield was 0.59-1.85 q/ha less, but the deviations did not reach significance.

Taking into account the effect of the interaction between soil works and fertilisation in winter two-row barley in 2015 (Table 4 and Figure 1), we see that when using ploughing + disking (2x) the combinations of macro elements differentiated from the perspective of yields.

When fertilising with $N_{60}P_{0}K_{60}$, soil works had a higher influence on grain yield. Thus, preparing the soil using disking (2x) alone allowed a significant increase in yield compared to the variant scarification + disking (2x). With the other fertilisation types, soil preparation type had no significant influence on yield.

Table 4

Effect of soil works and fertilisation on yield in winter two-row barley (2015)

Fertilisation	Soil works				
	A1	A2	A3	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
$N_0P_0K_0$	49.29 e	47.80 g	46.99 h	48.03±0.43	2.66
$N_0P_{60}K_0$	60.52 cd	58.78 ef	57.28 fg	58.86±0.50	2.57
$N_0P_0K_{60}$	57.15 d	56.19 f	53.13 g	55.49±0.64	3.47
$N_{60}P_0K_0$	62.10 bcd	59.99 def	58.89 def	60.33±0.49	2.46
$N_{60}P_{60}K_0$	60.02 cd	61.98 cde	62.77 cde	61.59±1.04	5.09
$N_{60}P_0K_{60}$	xy59.53 cd	x63.92 bcde	y57.70 efg	60.38±1.51	7.49
$N_0P_{60}K_{60}$	63.73 bc	60.84 def	60.02 def	61.52±0.59	2.86
$N_{60}P_{60}K_{60}$	66.99 b	65.42 abcd	63.60 bcd	65.34±0.53	2.42
$N_{90}P_{60}K_{60}$	69.51 ab	66.89 abc	68.50 ab	68.30±0.41	1.82
$N_{90}P_0K_{60}$	67.80 ab	67.98 ab	67.09 abc	67.62±0.15	0.69
$N_{90}P_{60}K_0$	68.75 ab	67.86 ab	67.90 abc	68.17±0.18	0.78
$N_{90}P_{90}K_{60}$	72.83 a	69.73 a	69.05 a	70.54±0.59	2.52
$\bar{x} \pm s_{\bar{x}}$	63.18±1.09	62.28±1.01	61.08±1.12	62.18±0.62	
$S_{\%}$	10.33	9.69	10.99	10.34	

- Soil works $DL_{5\%}$ = 5.30 q/ha, $DL_{1\%}$ = 7.03 q/ha, $DL_{0.1\%}$ = 9.13 q/ha
- Fertilisation $DL_{5\%}$ = 5.44 q/ha, $DL_{1\%}$ = 7.22 q/ha, $DL_{0.1\%}$ = 9.38 q/ha

A_1 – Ploughing +Disking (2x); A_2 – Disking (2 x); A_3 – Scarification + Disking (2x)

Are considered significant differences between combinations noted with different letters (a, b, c…)

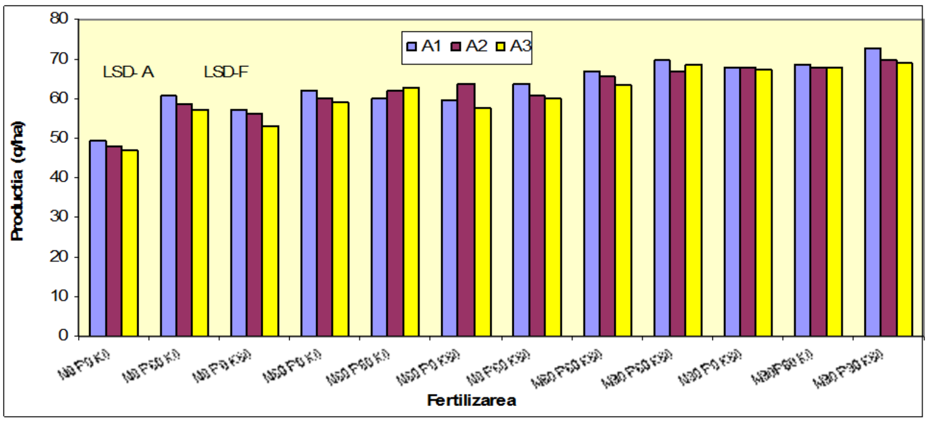

Fig. 1. Effect of soil works and fertilisation on yield in winter two-row barley (2015)

When using ploughing + disking, fertilisation determined a variation in yield of 23.54 q/ha. Compared to the control variant, the other combinations generated significant yield increases ranging between 15% in the variant $N_0P_0K_{60}$ and 47% in the variant $N_{90}P_{90}K_{60}$. Unilateral nitrogen treatment produced 158-495 kg/ha more than phosphorus and potassium unilateral treatments. The association of the three macro elements in the variant 60 kg a.s. had a significantly superior effect on yield compared to the associated effects of two macro elements. Treatments with 180-230 kg a.s./ha generated increases in yield of 7-27% compared to the other combinations of macro elements.

When preparing the soil using two diskings, fertilisation generated a yield span of 2,193 kg/ha ranging between 4,780 kg/ha in the control variant and 6,973 kg/ha in the variant $N_{90}P_{90}K_{60}$. Therefore, the variant with the maximum of active substance produced significantly higher yields (10%) to the variant with maximum 120 kg a.s. Applying unilaterally 60 kg of phosphorus produced more (839-1,098 kg/ha) than unilateral use of nitrogen (1,219 kg/ha). On this agri-fund, applying the three macro elements combined at a rate of 60 kg a.s. allowed an increase in yield but the increases were not significant compared to the associated application of pairs of these macro elements.

When using scarification + disking (2x), treatment variability ranged between 4,699 and 6,905 kg/ha, i.e. between the control variant and the variant with maximum macro elements. Unilateral fertilisation with 60 kg of each macro element had a significant yield materialised in increases of 13-25%, higher when applying nitrogen fertilisers. In exchange, applying unilaterally 60 kg of nitrogen a.s./ha had a significant efficacy equal to that of applying 60 kg a.s. of two or even three macro elements. Fertilisation with $N_{90}P_{90}K_{60}$ generated a significant increase in yield of over 545 kg/ha compared to the variants treated with 180 kg a.s./ha.

According to the data presented in Table 5, about 90% of the yield variability in winter two-row barley in 2015 could be the result of the influence of the three macro elements in this regression model. Nitrogen fertilisation had a distinctly significant major influence on yield of about 68.53%, followed by phosphorus fertilisation (15.34%) and potassium fertilisation (5.88%). We also see that the alteration of the number of grains per plant had a low insignificant impact on yield.

Table 5

Analysis of multiple regression variance between yield in winter two-row barley and nitrogen, phosphorus and potassium fertilisation rates (2015)

Variability source	SP	GL	S^2	F test
Regression	400.51	3	133.50	F=23.36**
Rate of N (x_1)	305.80 (68.53%)	1	305.80	F=53.50**
Rate of P (x_2)	68.45 (15.34%)	1	68.45	F=11.97**
Rate of K (x_3)	26.26 (5.88%)	1	26.26	F=4.59**
Other sources	45.73 (10.25%)	8	5.72	
Total	446.24	11		

$y = 51.99 + 0.1162x_1 + 0.08\ x_2 + 0.05\ x_3$; $R^2 = 0.8975$; $R^2_a = 0.8591$; R = 0.9888; SDE = 2.39 q/ha; DW = 2.16

This regression model allows a significant evaluation of the yield with an error of only ±239 kg. Taking into account that the Durbin-Watson index is above 1.4, the possible errors of trial results are not correlated and the order of macro elements in thee regression equation does not influence estimated yield values. The low deviations between the two determination coefficients show that determinations allowed a proper estimation of the yield in winter two-row barley in 2015.

Conclusions

Research on the influence of soil works and fertilisation on yield allow us to draw the following conclusions:

1. Soil works and fertilisation had significant influences on yield in winter two-row barley in 2015.
2. The three soil preparation variants allowed yields ranging between 61.08 q/ha when using scarification + disking (2x) and 63.18 q/ha when using ploughing + disking (2x), with lo variability (1.70%) between the soil works.
3. When using ploughing + disking, fertilisation determined a yield variation of 23.54 q/ha.
4. When applying two diskings, fertilisation generated a yield span of 2,193 kg/ha ranging between 4,780 kg/ha in the control variant and 6,973 kg/ha in the variant $N_{90}P_{90}K_{60}$.
5. When using scarification + disking (2x), treatment variability ranged between 4,699 and 6,905 kg/ha, i.e. between the control variant and the variant with maximum macro elements.
6. Different macro element combinations produced 48.03 q/ha in the control variant and 70.54 q/ha in the variant $N_{90}P_{90}K_{60}$, with medium variability (10.24%).
7. Unilateral nitrogen fertilisation had a significantly higher effect on yield: 0.43% per kg a.s. compared to the unilateral effects of phosphorus (0.38% per kg a.s.) and potassium (0.6% per kg a.s.).

8. Compared to the trial mean, we noted particularly four variants – $N_{90}P_{90}K_{60}$, $N_{90}P_{60}K_{60}$, $N_{90}P_{60}K_{0}$ and $N_{90}P_{0}K_{60}$ – that had a higher efficacy materialised in yield increases ranging between 544 and 836 kg/ha.

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