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Research Article

Barleycorn Productivity and Quality in Relation to the Surface Slope

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ABSTRACT
Field relief undoubtedly defines to a large degree soil water, air and nutrients supply, also influencing the field microclimate. The aim of the study was to investigate the impact of field surface patterns on productivity and brewing value of barley and malt at the foothills of the North Caucasus. It was found that crop yield at lower relief elements was, respectively, 7.1% and 28.6% higher comparing with the harvest at the top of the slope. Such increase in crop yield can be explained by higher fertility of the soil in lowland areas, caused by moving of the richest soil fractions from the top to the bottom of the slope due to erosion. It was shown that barley productivity increases from the top to the bottom parts of a hill, while the brewing value of the corn and malt significantly declines. Therefore, cultivation of malting barley in the lower parts of the slopes is unreasonable; crops should be confined to the tops.

Keywords: field relief; barley; malt; productivity; quality; protein fractional composition

INTRODUCTION
Field relief undountedly defines to a large degree soil water, air and nutrients supply, also influencing the field microclimate (Posypanov et al. 2006). Studies by L. R. Rainer and I. Shtainberg (1980) revealed that soil water supply of the top parts and the southern slopes of the hills in the south-eastern part of Estonia was significantly worse, compared with any other area. Nitrogen compounds supply, especially at the tops of the hills, was also lower, while potassium and phosphorus content in the soil of the upper parts and the southern slopes was slightly higher. As a result of more favourable conditions of the northern slopes, barley productivity was 1.5-2-folds higher than that in other aspects (Rainer, Shtainberg 1980). F.M. Prutskov studied the impact of the 9° slope of the terrain relief on the quality of barleycorn. It was shown that the harvest from the bottom part of the slope was, according to most criteria, of lower quality, than the harvest from other levels. The author came to the conclusion that it would be reasonable to harvest and store separetly the crops from the areas, various in productivity and relief, in order to use the production of different quality for different purposes. The crops in the lower parts of the slope, in his opinion, should be used as fodder (Prutskov 1982).

SUBJECTS AND METHODS OF STUDY
The aim of the study was to investigate the impact of field surface patterns on productivity and brewing value of barley and malt at the foothills of the North Caucasus. The research was carried out in the premises of Joint-Stock

Company NP «Chegem», Limited company «MELT» and Public corporation «Khalvichnyi zavod «Nalchiksky» in 2012-2014.Study subjects included the varieties of the winter barley - Master, Mikhailo, Kozyr, Dobrynya 3 – and summer barley – Priazovsky 9, Getman, Vikont and Mamlyuk with the seeding rate of 5.0 mln viable seeds per hectare.

The experiments were carried out as follows:

Experimental design:

1. Top of a hill (10-12°);
2. Slope of a hill (6-7°);
3. Foot of a hill (2-3°).

The seeds were sown in rows during the first decade of October in case of the winter barley and during the first decade of April in case of the summer barley; the seeding rate was 5.0 mln viable seeds per hectare. Early potato was the preceding crop. The following varieties of the winter and summer barley were studied: Mikhailo, Kozyr, Dobrynya 3 and Priazovsky 9, Vikont and Mamlyuk. Malting process included barley refining, sorting, soaking up to 45% moisture in water of 12-13°C temperature, germination at the temperature of 18-19°C during the first two days, followed by daily decrease in temperature by 1-2°C, until it reached 13-14°C by the end of the process. Barley was malted for 6-7 days; prepared malt was moistened up to 44-45%. Malt moisture decreased in course of drying from 45% to 3.5%-4% (Khokonova 2015a). Then deculming was performed, and malt was stored for the purposes of ageing. Standard protocols generally accepted in brewing industry were used for analytical studies (Ermolaeva 2004). Malting wastes were calculated at each stage of the malting process and summed up later. Mature malt after drying and 1 month of ageing was used to measure malting wastes, protein content, extraction rate (on dry basis), malt hardness, Kobach index, mash colour and pH (Khokonova 2015a).

RESULTS AND DISCUSSION

The results of the study showed that field relief had marked impact on the productivity of the winter and summer barley (Table 1).

Table 1. Productivity (tons/hectare) of barley varieties cultivated in fields with different slopes

№	Varieties	Relief element and slope		
		top of the hill (10-12°)	slope of the hill (6-7°)	foot of the hill (2-3°)
Winter varieties				
1.	Mikhailo	3.3	3.5	4.0
2.	Kozyr	3.5	3.7	4.2
3.	Dobrynya 3	3.0	3.3	3.8
Mean		3.3	3.5	4.0
LSD_{05}		0.24	0.31	0.36
Summer varieties				
4.	Priazovsky 9	2.5	2.8	3.4
5.	Vikont	2.3	2.6	3.1
6.	Mamlyuk	2.1	2.4	3.0
Mean		2.3	2.6	3.2
LSD_{05}		0.21	0.23	0.30

Average value of productivity for both types (winter and summer barley) at the top of the hill was 2.8 tons/hectare, 3.0 tons/hectare at the slope of the hill, 3.6 tons/hectare at the foot of the hill. In other words, crop yield in lower relief elements was 7.1% and 28.6% respectively higher, when compared with the harvest at the top of the slope. Such increase in crop yield can be explained by higher fertility of the soil in lowland areas, caused by the movement of the richest soil fractions from the top to the bottom of the slope due to erosion. It should be noted that the winter varieties of barley provided higher yield (3.6 tons/hectare) in all the elements of the relief, compared with the summer varieties (2.7 tons/hectare); the mean difference over the period of studies was 33.3%, considering 43.5% at the top of the hill, 34.6% at the slope of the hill, 25.0% at the foot of the hill. Therefore, the winter varieties of barley are better adapted to poor soils than the summer varieties (Fedotov et al. 2004). Kozyr is the

most productive variety among the studied winter barley varieties. Average yield over different elements of relief and years of study was 3.8 tons/hectare, which was 0.2 and 0.4 tons/hectare more, than that of Mikhailo and Dobrynya 3, respectively. This variety was also the most tolerant to lower soil fertility at the top of the slope. Decrease in productivity, when compared with the values at the foot of the hill, was 16.7%, while in case of other varieties the yield was 17.5-21.1% lower. Priazovsky 9 had the highest productivity of all the summer barley varieties, exceeding the yield of two other varieties by 0.2 tons/hectare. The summer varieties had similar reaction to the field slope (the yield was 25.8%-28.1% lower at the top of the hill), which was more prominent (26.8%) than in the winter varieties (18.4%). Field relief had impact on weight, size and other brewing qualities of barleycorn. The summer varieties of barley had higher corn size, 81.9% of large corns on average over different varieties and elements of relief, compared with 78.5% in the winter varieties (Table 2).

Table 2. Impact of field relief on the brewing quality of barleycorncorn

Relief element and slope	Varieties	Corn size, %	Weight of 1000 corns, g	Protein content,%	Extraction rate,%
1	2	3	4	5	6
Winter varieties					
Top of the hill (10-12°)	Mikhailo	77.0	36.7	11.6	78.8
	Kozyr'	79.0	37.9	11.7	78.9
	Dobrynya 3	72.0	34.4	11.9	76.4
Mean		76.0	36.3	11.7	78.0
Slope of the hill (6-7°)	Mikhailo	79.0	38.5	12.0	76.2
	Kozyr	81.0	39.0	12.1	76.0
	Dobrynya 3	76.0	37.8	12.5	75.3
Mean		78.6	38.4	12.2	75.8
Foot of the hill (2-3°)	Mikhailo	81.0	40.0	13.5	75.7
	Kozyr'	83.0	41.3	13.7	76.0
	Dobrynya 3	79.0	38.2	13.9	74.5
Mean		81.0	39.8	13.7	75.4
LSD_{05}				1.39	
Summer varieties					
Top of the hill (10-12°)	Priazovskii 9	82.0	42.0	10.2	79.4
	Vikont	79.0	41.5	10.7	77.8
	Mamlyuk	77.0	40.8	11.1	76.9
Mean		79.3	41.4	10.6	78.0
Slope of the hill (6-7°)	Priazovskii 9	84.0	43.4	10.8	79.1
	Vikont	83.0	42.0	11.2	76.8
	Mamlyuk	80.0	41.9	11.8	75.4
Mean		82.3	42.4	11.2	77.1
Foot of the hill (2-3°)	Priazovsky 9	86.0	43.5	11.7	78.0
	Vikont	84.0	43.1	11.9	75.7
	Mamlyuk	82.0	42.6	12.5	75.1
Mean		84.0	43.0	12.0	76.2
LSD_{05}				1.12	

The proportion of large corns in the winter varieties increased from the top to the middle and bottom of the slope from 76.0% to 78.6% and 81.5%, respectively; in the summer varieties – from 79.3% to 84.0%. According to these data, corn size can be considered to be one of the parameters of higher productivity and higher quality of the studied crops. Kozyr had the highest proportion of large corns among the studied varieties of the winter barley – 81% on average over different elements of relief and years of study. This parameter was 2.0% and 5.3% lower in Mikhailo and Dobrynya 3, respectively. In case of the summer varieties, Priazovsky 9 was marked by the highest value of this parameter – 84%, while in Vikont and Mamlyuk it was 2% and 4% lower, respectively. The results of the analysis of 1000 corns weight are consistent with the data on the corn size. Mean weight over the winter barly varieties was

38.2 g, decreasing from 39.8 g at the foot of the hill to 38.4 g at the slope and 36.3 g at the top of the hill. The highest average corn weight over different elements of relief and years of study, equaled to 39.4 g, was observed in Kozyr variety, exceeding the values for Mikhailo and Dobrynya 3 by 1.1 and 2.6 g, respectively. Mean weight of 1000 corns in the summer barley varieties over the investigated varieties and years of study was 42.3 g, which is 4.1 g higher than in the winter varieties. Apart from that, this parameter varies the same way, as in the case of the winter varieties - total average corn weight over different varieties and years of study increased from 41.4 g at the top of the hill to 42.4 g at the middle part and 43.0 g at the bottom, while the average corn weight at the top of the hill was 41.4 g, compared to 36.3 g in the winter varieties, 42.4 g at the slope (38.4 g in the winter varieties), and 43.0 g at the foot of the hill (39.8 g in the winter varieties). Among the summer varieties, Priazovsky 9 had the highest values of the mean weight, as well as of the corn size. The mean weight was 43.0 g, 0.8 g and 1.2 g higher than in Vikont and Mamlyuk, respectively. Larger corns had higher proportion of endosperm, accumulate more starch and, subsequently, sugars. Such corns are also marked by higher extraction rate. Therefore, the values of the latter are consistent with corn size and weight (Khokonova 2016b). Mean extraction rate of the summer varieties over the factors, listed above, was 77.1%, while in the winter varieties it was 76.4%. It decreases from 78.0% at the top of the hill to 75.4% at the foot of the hill in the winter varieties, and from 78.0% to 76.2% in the summer varieties. Considering individual varieties, the pattern is the same as in the case of corn size and weight: Kozyr had the highest value among the winter varieties and Priazovsky 9 – among the summer vareities. However, in the context of brewing value, there is an undesirable consequence of higher soil fertility and associated with its corn size, weight of 1000 corns and extraction rate – increased protein content. The summer varieties of barley are more preferable in this respect, as the average protein content over the factors concerned and different years of study was 11.3%, compared to 12.5% in the winter varieties. The protein content increased from 11.7% at the top of the hill to 13.7% in the winter varieties, and from 10.3% to 12.0% in the summer varieties. Field relief had significant and very consistent impact on the protein fractional composition of corns (Table 3).

Table 3. Impact of the field relief on the protein fractional composition of barleycorns, % of total extracted nitrogen

Relief element and slope	Varieties	Nitrogen of the protein fractions, soluble in				Non-protein nitrogen
		water	salt	alcohol	alcali	
Winter varieties						
Top of the hill (10-12°)	Mikhailo	9.9	17.5	26.0	26.0	23.0
	Kozyr	9.6	16.8	25.8	25.8	22.8
	Dobrynya 3	10.0	17.1	26.8	26.8	23.6
Slope of the hill (6-7°)	Mikhailo	8.6	15.8	30.8	30.8	19.9
	Kozyr	8.3	15.9	30.3	30.3	19.4
	Dobrynya 3	9.1	16.1	31.1	31.1	20.6
Foot of the hill (2-3°)	Mikhailo	7.8	14.2	32.6	32.6	15.0
	Kozyr	7.0	13.4	31.9	31.9	14.3
	Dobrynya 3	8.0	15.7	35.2	35.2	15.9
Summer varieties						
Top of the hill (10-12°)	Priazovsky 9	8.1	15.4	19.6	23.1	20.0
	Vikont	8.8	15.9	10.0	24.2	20.4
	Mamlyuk	8.9	16.2	20.7	25.7	21.4
Slope of the hill (6-7°)	Priazovsky 9	6.8	13.9	20.9	27.6	19.5
	Vikont	6.9	14.3	22.8	29.1	19.8
	Mamlyuk	7.7	15.0	21.9	30.0	20.1
Foot of the hill (2-3°)	Priazovsky 9	5.7	13.3	22.1	30.9	16.9
	Vikont	6.0	14.0	23.9	31.7	17.6
	Mamlyuk	6.6	14.4	23.2	32.1	18.8

The results of the study showed that the average content of water-soluble nitrogen fractions over different barley varieties, types, and years of study decreased from 9.2% at the top of the hill to 7.9% at the slope and 6.8% at the foot of the hill; the content of salt-soluble fractions – from 16.4% to 15.2% and 14.2%, respectively; the content of non-protein nitrogen – from 21.8% to

19.9% and 16.4%, respectively. However, the content of alcohol-soluble fractions increased over the same range of relief elements from 23.2% to 26.2% and 28.2%; the content of alkali-soluble – from 25.2% to 29.8% and 32.4%. Therefore, the corns of the barley winter and summer varities, cultivated at the top of the hill, contained the protein fractions of the highest biological value, while the harvest from the foot of the hill was marked by the least valuable fractions. Apparently, under lack of nitrogen in soil, barley plants synthesize only the most essential fractions of protein, while the plants cultivated at the foot of the hill, in the soil with high nitrogen content, produced more storage proteins with slightly lower biological value. The summer barley varieties had no advantage over the winter varieties in terms of the protein fractional composition. Moreover, the average content of water-soluble fractions in the corns of the winter varieties over the relief elements, types and years of study was 8.7%, compared to 7.3% in the summer varieties; the content of salt-soluble fractions – 15.8% and 14.7%. At the same time, the content of less valuable fractions was higher: the content of alcohol-soluble fractions in the winter varieties was 30.0%, compared to 21.6% in the summer varieties; the content of alkali-soluble fractions – 30.0% and 28.3%, given equal levels of non-protein nitrogen – 19.

Dobrynya 3 should be considered to have the best protein fractional composition among the winter varieties, with the content of water-soluble (9.0%), salt-soluble (16.3%) and non-protein (20.0%) fractions, respectively, 0.7%, 0.9% and 1.2% higher than in Kozyr and 0.2%, 0.5% and 0.7% higher than in Mikhailo. At the same time, the content of alcohol- and alkali-soluble fractions was 31.0%, compared with 29.3-29.8% in other varieties. Mamlyuk is marked by the best protein fractional composition among the summer varieties. Average content of water-soluble fractions in its corns over the relief elements and years of study was 7.7%, content of salt-soluble fraction was 15.2%, content of non-protein fraction – 20.1%, which was, respectively, 0.5-0.8%, 0.5-1.0% and 0.8-1.3% more than in other varieties. The quality of the experimental malt and mash is strongly influenced by the field slope, the variety and the type of barley. In the summer barley varieties, the average malting loss over the elements of the slope, the types and years of study was 8.2%, while in the winter varieties it was 0.5% larger. Kozyr is an outstanding variety among the latter, with malting loss equal to 8.7%, compared to 9.0% and 9.4% in Mikhailo and Dobrynya 3, respectively (Table 4).

Table 4. Impact of the field relief on the malt quality

Relief element and slope	Varieties	Malting loss, %	Extraction rate, %			Malt hardness, Brabender units	Colour value, iodine cm^3/100 cm^3 of water
			fine grind	coarse grind	discrepancy		
Winter varieties							
Top of the hill (10-12°)	Mikhailo	9.7	79.2	77.3	1.9	83	3.3
	Kozyr	9.5	79.6	77.9	1.7	81	4.2
	Dobrynya 3	10.1	79.0	76.7	2.3	85	3.7
Slope of the hill (6-7°)	Mikhailo	7.3	78.0	75.4	2.6	94	2.9
	Kozyr	6.9	78.7	76.8	1.9	91	3.0
	Dobrynya 3	7.9	77.5	74.4	3.1	97	2.6
Foot of the hill (2-3°)	Mikhailo	9.9	74.2	71.0	3.2	117	2.2
	Kozyr	9.6	75.1	72.4	2.7	114	2.8
	Dobrynya 3	10.3	72.1	68.1	4.0	119	2.0
Summer varieties							
Top of the hill (10-12°)	Priazovskii 9	8.3	81.0	79.8	1.2	70	4.8
	Vikont	8.6	80.3	78.7	1.6	72	4.5
	Mamlyuk	8.9	77.2	75.3	1.9	75	4.3
Slope of the hill (6-7°)	Priazovsky 9	6.7	80.2	78.5	1.7	78	4.1
	Vikont	7.4	79.1	77.1	2.0	80	3.4
	Mamlyuk	7.9	76.7	74.1	2.6	84	3.0
Foot of the hill (2-3°)	Priazovsky 9	8.3	78.0	76.1	1.9	90	3.2
	Vikont	8.7	77.3	74.7	2.6	92	2.9
	Mamlyuk	9.0	75.0	71.8	3.2	99	2.6

The least rate of malting loss was observed in case of the harvest gathered at the slope of the hill – 7.4% on average over the listed variants and years, whereas at the top and the foot of the hill it increased up to 9.2% and 9.3%, respectively. However, considering the extraction rate, malt hardness and mash colour, the barley from the top of the slope had higher brewing quality. For instance, the average extraction rate for the fine grind and the discrepancy between the extraction rates for the fine and the coarse grind, was, respectively, 79.4% and 1.8% in case of the barley from the top of the hill; 78.4% and 2.3% in case of the production from the slope; 75.3% and 2.9% in case of the harvest fron the foot of the hill. Malt hardness over the same relief elements was 78 Brabender units at the top, 88 – at the slope and 106 – at the foot of the hill, mash colour values – 4.1, 3.2 and 2.6 cm^3 of iodine/100 cm^3 of water, respectively.

The winter varieties of barley differed from the summer ones by higher rates of malting losses (8.7% versus 8.2% in the summer varieties), malt hardness (98 Brabender units versus 82), but, at the same time, it had relatively low extraction rate (77.1% versus 78.3% in the summer varieties) and colour values (2.9 cm^3 of iodine/100 cm^3 of water against 3.6). Among the winter baley varieties, Dobrynya 3 had the highest average values of malting loss (9.4%) and malt hardness (100 Brabender units) over the relief elements, while Kozyr was marked by the highest fine grind extraction rate (77.8%) and colour value (3.3 cm^3 of iodine/100 cm^3 of water). Considering the summer varieties, Priazovsky 9 had the highest fine grind extraction rate (79.7%), Vikont – the highest malting loss (8.2%) and colour value (3.6 cm^3 of iodine/100 cm^3 of water), Mamlyuk – the highest malt hardness (86 Brabender units).

The results of the study suggest that barley productivity increases from the top to the bottom parts of the hill, while the brewing value of corn and malt significantly declines. Therefore, cultivation of malting barley at lower parts of the slopes is unreasonable; the crops should be confined to the tops.

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