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Potato yield and tuber quality in 75 cm and 90 cm wide ridges

Rajko BERNIK[1], Tone GODEŠA[2], Peter DOLNIČAR[3], Filip VUČAJNK[4]

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ABSTRACT

In 2002, 2003, and 2004, a field trial was carried out in three locations in Slovenia, i.e., Pšata, Brnik, and Brežice with two different inter-row widths (IRWs) of 75 cm and 90 cm using three different potato cultivars (i.e., Agria, Bright, and Carlingford). The aim of this trial was to determine the influence of inter-row width (75 cm or 90 cm) with three potato cultivars on the market yield, the yield of green tubers, the cross-sectional area of the ridge, and the percentage of tubers with a hollow heart or blackspot. The trial was designed in the form of split plots with five repetitions. In the years with abundant rainfall during the period of growth (2002 and 2004), when plants completely covered the ground, the market yield at the 90 cm IRW was higher than at the 75 cm IRW. In 2003, however, the market yield was higher at the 75 cm IRW. The yield of green tubers was lower at the 90 cm IRW than at the 75 cm IRW, due to a larger cross-sectional area of the ridge (> 1000 cm^2). Thus, the soil covering of tubers in the ridge was better. The hollow heart and blackspot disorders affecting the tubers depend more on the susceptibility of a particular cultivar and the meteorological conditions during the period of growth than the IRW. The findings showed that the Agria cultivar was more susceptible to the hollow heart disorder, particularly in the years with a higher yield with thicker tubers (2002 and 2004). The Bright cultivar was affected by blackspot in 2003, the year with a lack of rainfall.

Keywords: potato, ridge, cultivator, ridger, inter-row width, cultivar

IZVLEČEK

PRIDELEK TER KAKOVOST GOMOLJEV PRI 75 IN 90 CM ŠIROKIH GREBENIH

V letih 2002, 2003 in 2004 smo na Pšati, Brniku in v Brežicah izvajali poljski poskus z dvema medvrstnima razdaljama (MVR) 75 in 90 cm ter s tremi sortami krompirja Agria, Bright in Carlingford. Namen poskusa je bil ugotoviti vpliv MVR 75 in 90 cm pri treh sortah krompirja na tržni pridelek gomoljev, na pridelek zelenih gomoljev, na površino prečnega preseka grebena in na odstotek gomoljev z votlim srcem in rjavo pegavostjo. Poskus je bil zasnovan v obliki deljenih blokov s petimi ponovitvami. V letih z dovolj padavinami v rastnem obdobju (leto 2002 in 2004), ko so rastline popolnoma prekrile tla, je bil tržni pridelek pri MVR 90 cm višji kot pri MVR 75 cm. Ravno nasprotno je bilo v letu 2003, ko je bil tržni pridelek višji pri MVR 75 cm. Pridelek zelenih gomoljev je bil pri MVR 90 cm nižji kot pri MVR 75 cm zaradi večje površine prečnega preseka grebena, ki je znašala več kot 1000 cm^2. To je pomenilo boljšo pokritost gomoljev z zemljo v grebenu. Votlo srce in rjava pegavost na gomoljih sta bolj odvisni od občutljivosti sorte in vremenskih razmer v rastnem obdobju kot od MVR. Izkazalo se je, da je sorta Agria bolj občutljiva na votlo srce predvsem v letih z visokimi pridelki in debelimi gomolji (leto 2002 in 2004). Pri sorti Bright se je rjava pegavost pojavila v letu 2003, ko je bilo pomanjkanje padavin.

Ključne besede: krompir, greben, okopalnik, osipalnik, medvrstna razdalja, sorta

[1] Assist. Prof., Ph.D., University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Jamnikarjeva 101, SI-1111 Ljubljana, e-mail: rajko.bernik@bf.uni-lj.si

[2] M.Sc., Agricultural Institute of Slovenia, Hacquetova 17, SI-1000 Ljubljana

[3] M.Sc., Agricultural Institute of Slovenia, Hacquetova 17, SI-1000 Ljubljana

[4] M.Sc., Jamnikarjeva 101, SI-1111 Ljubljana

1 INTRODUCTION

Constant amelioration of potato cultivars in terms of fertility enhancement constrains potato producers from increasing the ridge volume. One option is to apply a wider inter-row width (IRW). The latter is, however, largely dependent on tractor's wheel spacing, as well as the machinery used in potato production. In the Netherlands, the predominant IRW is 75 cm. However, some potato producers have, in recent years, started to cultivate at the 90 cm IRW (Spiess and Heusser, 1995). A wider IRW allows more soil to be used in order to shape sufficiently high ridges, while the lateral sides of the ridge suffer less pressure from tractor's wheels. At harvest time, the higher soil volume additionally protects tubers from being damaged. Furthermore, less time is spent for the cultivation and harvesting of a particular area (Bouman, 1998; van der Zaag, 1992).

The better the conditions for potato growth, the higher the inter-row width may be (Professional ..., 2005; Seed ..., 2001). Field trials performed in the Netherlands since the 1970s show that market yields are higher at the 90 cm IRW than at the 75 cm IRW (Kouwehoven and Perdok, 2000). Moreover, the secondary growth of tubers is not as strong; there is a smaller yield of non-market tubers (< 50 mm) and a 20% higher yield of market tubers (> 50 mm). Beukema and van der Zaag (1990) state that, if an undisturbed growth of haulm is ensured, the yield at the 90 cm IRW will not be decreased. If the growth of haulm is, however, disturbed, the soil will not be completely covered by leaves, which will cause a greater evaporation of water from the soil and consequently result in a lower yield.

The yield of green tubers not suitable for sale and further processing also influences the tuber quality. Kouwenhoven *et al.* (2003) determined that the yield of green tubers was smaller at the 90 cm IRW than at the 75 cm IRW. This was due to a larger cross-sectional area of the ridge, and a better soil covering of tubers.

When subjected to stress, potato tubers can develop physiological disorders, such as a change of shape, their usefulness, or appearance (Dolničar *et al.*, 2004). These disorders diminish tuber quality. The hollow heart disorder occurs on thick tubers of only certain potato cultivars. It causes the centre of a tuber to become hollow, while the colour of the medulla surrounding it remains unchanged. This disorder is influenced by a quick growth of tubers during the rainfall following a dry spell, by low soil temperatures during the formation of tubers, and the increased soil moisture, which is connected with an intensity of tuber growth (Dolničar, 1997; Dolničar *et al.*, 2004; Kus, 1994; Bugarčić, 2000). During very hot summers, thick tubers of some potato cultivars (especially those planted on sandy soil) develop small brown-coloured spots. These spots are in fact groups of damaged and dead cells in tubers' medulla. The disorder is called blackspot and can be increased by high temperatures associated with drought stress (Dolničar, 1997; Dolničar *et al.*, 2004; Kus, 1994).

The aim of the trial was to determine the influence of IRW (75 cm or 90 cm) and potato cultivar on the market yield, the yield of green tubers, the cross-sectional area of the ridge, and the percentage of tubers with the hollow heart or blackspot disorders. In Slovenia, potatoes are still produced at IRWs that do not exceed 70 cm. The 75 cm IRW is currently in use by bigger, more specialized potato producers who use modern tractors with the standard 150 cm wheel spacing and more state-of-the-art potato-production machinery. The 90 cm IRW, however, is not in use at all. Furthermore, not much research has been performed on the influence of IRW on the occurrence of the hollow heart or blackspot disorders.

2 MATERIALS AND METHODS

The trial included two IRWs (75 cm and 90 cm) and three potato cultivars (i.e., Agria, Bright, and Carlingford). It was carried out in three different locations (Brnik, Pšata in the vicinity of Ljubljana, and Brežice) in three consecutive years (2002, 2003, 2004). It was designed in the form of split plots with five repetitions. Each plot included two randomly positioned IRWs (75 cm and 90 cm) representing the two main plots. Within each IRW, the three potato cultivars were randomly positioned in order to form subplots. The main plots measured 15m in length, while subplots were 5m long. On each main plot, four rows of potato were planted. All measurements were carried out in the inner two rows.

One of the factors determining the choice of these three cultivars was the fact that all of them are able to produce high yields in favourable meteorological conditions. The occurrence of green tubers is, however, possible, especially at the smaller IRW. The Agria cultivar produces a smaller quantity of very thick tubers. The Bright cultivar produces a medium quantity of thick tubers, while Carlingford grows a large quantity of medium-thick tubers. Moreover, all three cultivars may be subject to physiological disorders if exposed to unfavourable meteorological conditions. The Agria cultivar is sensitive to the hollow heart disorder. The Bright cultivar is sensitive to the blackspot disorder. When subjected to stress, the Carlingford cultivar produces tubers that are not

sufficiently big. Meteorological conditions varied throughout the trial years. In 2003, the average air temperature in the period from April to September was 3°C higher than the long-term average in the years 1961-1990. In that year, the rainfall total in the period between April and September was substantially lower. In 2002 and 2004, variations from the long-term average were much smaller (Table 1).

Table 1: The average air temperature (°C) and the rainfall total (mm) in the period between April and September in 2002, 2003, and 2004 compared to the long-term average in the years 1961-1990 in Brnik, Bežigrad, and Bizeljsko (°C) (Mekinda - Majaron, 1995; Meteorološki letopisi, 2005)

Year	Average temperature (°C)			Rainfall total (mm)		
	Bežigrad	Brnik	Bizeljsko	Bežigrad	Brnik	Bizeljsko
2002	17.5	15.6	17.4	799	746	612
2003	19.0	17.1	19.0	536	430	261
2004	16.8	14.8	16.6	861	866	629
1961-1990	16.1	14.7	16.0	784	768	607

The planting density was 45,000 tubers/ha. There was a 29.6 cm inter-tuber width in the row with a 75 cm IRW, and a 24.7 cm inter-tuber width with the 90 cm IRW. A modified 4-row IRW-forming machine was used to create planting furrows. Those were then prepared to be manually planted with all three potato cultivars. The planting depth was equal in both IRWs, and it allowed seed tuber tops to be levelled with the soil. The 75 cm and 90 cm ridges were shaped with a PTO-driven potato cultivator/ridger (University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Chair of Agricultural Engineering) (Figure 1). This machine is, in fact, a rotary tiller used for the cultivation of the inter-row space. Attached to its shaft are four rotors with blades. In order to set the IRW, rotors must be shifted along the shaft and placed into provided holes (Godeša, 2002). In the rear, a ridger forming 75 cm and 90 cm trapezoid-shaped ridges is attached (Figure 2). The rotation speed of the PTO shaft was 540 rpm, while the operating speed amounted to 1.5-3 km/h. At both IRWs, cultivation was carried out at a depth of 15 cm. Cultivation and ridging was performed a few days before the potato emergence. All further work concerning agricultural technology was carried out in accordance with good agricultural practice.

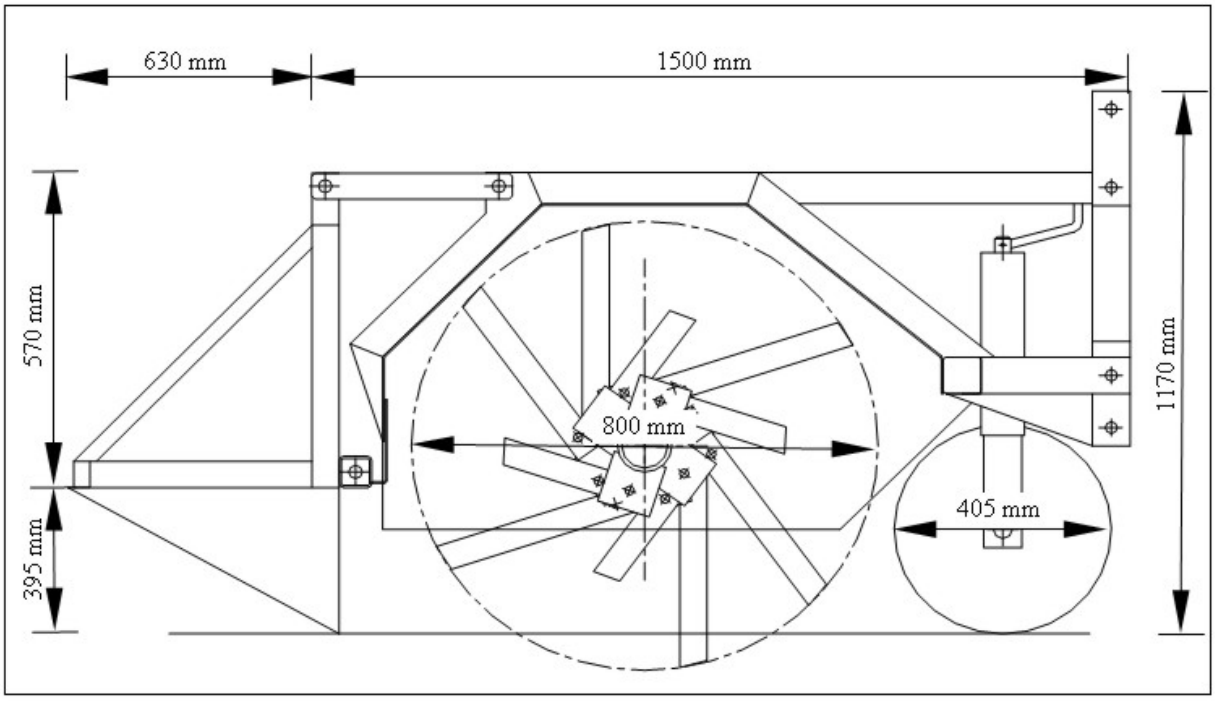

Figure 1: PTO-driven cultivator/ridger used for ridge shaping

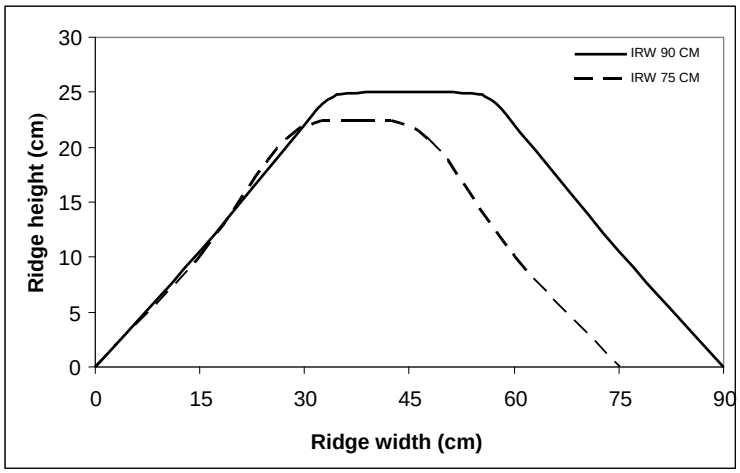

Figure 2: Ridge shape at the 75 cm and the 90 cm IRWs

On each subplot, the yield was harvested from the inner two rows in order to eliminate the impact of the marginal area. Tuber samples were then analysed at the Agricultural Institute of Slovenia. Each sample was placed into a selection device made of a frame, onto which nets were vertically placed. The screen meshes had diameters of 65, 55, 45, 35, and 25 mm. Only tubers smaller than 25 mm remained at the bottom of the device. The remaining tubers left on each net were then counted and weighed. Based on this data, the market-tuber yield (> 35 mm) was calculated. Furthermore, green tubers thicker than 35 mm were counted and weighed, and the yield of green tubers was calculated.

Physiological disorders occurring on tubers were determined by taking 10 tubers thicker than 45 mm from each sample and slicing them in half. Then, the number of tubers with hollow heart or blackspot disorder was determined. This data allowed us to calculate the percentage of tubers with the hollow heart and blackspot disorders.

Before the harvest, coordinates of the ridge were measured with a three-dimensional coordinate measuring device (University of Ljubljana, Biotechnical Faculty, Department of Agronomy, Chair of Agricultural Engineering). Based on these, the cross-sectional area of the ridge was calculated with the LabView program.

The basic data processing was carried out in Microsoft Excel. A statistical analysis was made using the Statgraph 4.0 program, while an analysis of variance was carried out pursuant to the procedure valid for the split-plot trial. Furthermore, a Duncan Multiple Range Test (α=0.05) was performed. When the interaction was statistically significant for the outcome, standard errors of the mean value difference were calculated.

3 RESULTS AND DISCUSSION

In all trial years and at all three locations, statistically significant differences occurred in the market yield of tubers according to the IRW (Table 2). In 2002 and 2004, market yields at the 90 cm IRW were higher than at the 75 cm IRW, amounting to 3.2-8.1 t/ha. In both years, the rainfall exceeded its long-term average (1961-1990) in all three locations. Plants were thus provided with an optimal water supply throughout the entire period of growth (April 1 – September 30). In 2003, market yields at the 75 cm IRW were higher than at the 90 cm IRW in all three locations. The differences between market yields oscillated from 3.2 t/ha to 5.8 t/ha. In that year, the rainfall was 248 mm, 338 mm, and 346 mm lower (in Pšata, Brnik, and Brežice, respectively) during the period of growth lasting from April 1 to September 30 when compared with the long-term average between 1961-1990 (Table 1). Rows in the plot with 90 cm IRW did not join, and so we assume that larger evaporation, lower water content, and higher temperature occurred in ridges. These results match the findings of Spiess *et al.* (2005), determining that market yields at the 90 cm IRW are larger than at the 75 cm IRW only when the soil has been optimally supplied with water. Beukema and van der Zaag (1990) offer similar findings. The results are only partially compatible with those gained by Kouwenhoven and Perdok (2000), who determined higher yields at the 90 cm IRW.

Table 2: Influence of IRW on the market yield of tubers (> 35 mm) in all three locations in 2002-2004 (t/ha) (Duncan's Test α=0.05)

Year	IRW (cm)	PŠATA	BRNIK	BREŽICE
2002	75	45.2[a†]	-*	53.1[a]
	90	53.3[b]	-	56.4[b]
2003	75	42.6[a]	23.2[a]	25.1[a]
	90	36.8[b]	20.0[b]	21.5[b]
2004	75	49.9[a]	44.8[a]	50.2[a]
	90	53.1[b]	51.7[b]	54.1[b]

† The same letters within a column in the same year and the same location are not statistically different.
* Tuber samples taken from the Brnik location in 2002 were mixed up and could not be analysed.

Statistically significant differences occurred according to the cultivar as well. They were, however, not as pronounced as with IRW (Table 3). In 2002, market yield of the Carlingford cultivar in Pšata was higher than with the other two cultivars. This was expected, as this cultivar is known to produce high yields during the years with an abundant rainfall. In 2003 the Bright cultivar had a higher market yield than other the two cultivars in the Pšata and Brežice locations. This year was extremely dry (the driest in 200 years), though this fact does not allow us to make any actual conclusions. In 2004, the market yield by the Agria cultivar in Brnik was significantly lower than with the other two cultivars. Furthermore, the market yield with the same cultivar was significantly higher than with the Bright cultivar in Brežice.

Table 3: Influence of the cultivar on the market yield of tubers (> 35 mm) in all three locations in 2002-2004 (t/ha) (Duncan's Test α=0.05)

Year	Cultivar	PŠATA	BRNIK	BREŽICE
2002	Agria	46.6[a†]	-*	52.8[a]
	Bright	40.0[a]	-	47.1[b]
	Carlingford	52.0[b]	-	55.1[a]
2003	Agria	38.2[a]	22.8[a]	24.2[a]
	Bright	42.8[b]	21.9[a]	28.3[b]
	Carlingford	36.1[a]	19.2[a]	21.9[a]
2004	Agria	49.7[a]	41.9[a]	52.9[a]
	Bright	53.7[a]	50.2[b]	47.2[b]
	Carlingford	50.7[a]	51.3[b]	51.3[ab]

† The same letters within a column in the same year and location are not statistically different.
* Tuber samples taken from the Brnik location in 2002 were mixed up and could not be analysed.

The yield of green-tubers at the 90 cm IRW was lower than at the 75 cm IRW in Brežice in 2002, in Pšata and Brnik in 2003, and in Pšata and Brežice in 2004 (Table 4). There were no green tubers at the 90 cm IRW in 2003, due to very low market yields. We assume that the low yield of green-tubers at the 90 cm IRW is interconnected with a larger cross-sectional area of the ridge. At the aforementioned IRW, it amounts more than 1000 cm^2 before the harvest, while at the 75 cm IRW it ranges from 752 to 874 cm^2 (Table 4). Such a cross-sectional area of the ridge at the 90 cm IRW ensures a better soil covering of tubers. Kouwenhoven *et al.* (2003) state that cultivars with tubers that are longer and have a wider horizontal span require ridges with a cross-sectional area exceeding 900 cm^2. Furthermore, the authors state that this can be achieved by enlarging the IRW from 75 cm to 90 cm. The obtained results correspond to the results gained by Kouwenhoven and Perdok (2000), Kouwenhoven *et al.* (2003), and Spiess *et al.* (2005), all of whom concluded that, at the 90 cm IRW, the percentage of green tubers was smaller than at the 75 cm IRW. There were no statistically significant differences in the yield of green tubers according to the cultivar.

Table 4: Influence of IRW on the yield of green tubers (> 35 mm) (t/ha) and the cross-sectional area of the ridge before the harvest (cm^2) in all three locations in 2002-2004 (Duncan's Test α=0.05)

Year	IRW	Green tubers (t/ha)			Cross-sectional area (cm^2)		
	(cm)	PŠATA	BRNIK	BREŽICE	PŠATA	BRNIK	BREŽICE
2002	75	1.2[a†]	-[*]	8.9[a]	799[a]	862[a]	815[a]
	90	0[a]	-	4.3[b]	1046[b]	1070[b]	1038[b]
2003	75	2.0[a]	1.5[a]	0.3[a]	812[a]	756[a]	874[a]
	90	0[b]	0.1[b]	0[a]	1100[b]	1065[b]	1151[b]
2004	75	2.3[a]	1.5[a]	2.0[a]	752[a]	776[a]	800[a]
	90	0.8[b]	0.6[a]	0[b]	1035[b]	1076[b]	1066[b]

†The same letters within a column in the same year and location are not statistically different.
* Tuber samples taken from the Brnik location in 2002 were mixed up and could not be analysed.

The choice of IRW did not affect the percentage of tubers with the hollow heart or the blackspot disorders. Both physiological disorders are, in fact, more dependent on the cultivar and meteorological conditions within an individual year than the IRW. In 2003 when the average air temperature during the period of growth was very high and soil water content was low hollow heart in tubers did not occur. This disorder generally occurs on thicker tubers in the years with higher yields (e.g. 2002 and 2004), while its occurrence is not very common in dry years when tubers are not as thick (e.g. in 2003). Hollow heart occurred predominantly with the Agria cultivar in 2002 and 2004, which was not entirely unexpected, since this cultivar is particularly susceptible to this disorder (Table 5). In Pšata and Brnik (2004), the percentage of tubers with the hollow heart disorder was statistically higher with Agria than with the other two cultivars. These results are in accordance with the statements of Dolničar (1997) and Kus (1994). A more serious occurrence of the blackspot disorder happened in 2003, a year with very high temperatures and lacking rainfall, which correspond with the findings of Dolničar (1997) stating that the occurrence of blackspot can be increased by high temperatures associated with drought stress. Particularly susceptible to this disorder is the Bright cultivar. In 2003, the latter had a statistically higher percentage of tubers with blackspot in all three locations in comparison with the other two cultivars. In 2002 and 2004, the occurrence of blackspot was less frequent because there was optimal precipitation, and air temperature was lower than compared to 2003. We also assume in these two years that there was a lower average soil temperature and higher water content in the ridges.

Table 5: Influence of the cultivar on the percentage of tubers with the hollow heart and blackspot disorders in all three locations in 2002-2004 (%) (Duncan's Test α=0.05)

Year	Cultivar	Hollow heart (%)			Blackspot (%)		
		PŠATA	BRNIK	BREŽICE	PŠATA	BRNIK	BREŽICE
2002	Agria	3.3[a†]	-[*]	3.3[a]	0[a]	-	6.7[a]
	Bright	0[a]	-	5.3[a]	4.7[a]	-	2.7[a]
	Carlingford	0[a]	-	4.0[a]	1.3[a]	-	6.0[a]
2003	Agria	0[a]	0.7[a]	0[a]	0[a]	0.7[a]	4[a]
	Bright	0[a]	0[a]	0[a]	26[b]	10[b]	14.7[b]
	Carlingford	0[a]	0[a]	0[a]	0[a]	1.3[a]	4[a]
2004	Agria	9.3[a]	8.7[a]	0.7[a]	3.3[a]	0[a]	0[a]
	Bright	2.0[b]	1.0[b]	0.7[a]	4.0[a]	0.7[a]	4.7[b]
	Carlingford	0[b]	0[b]	0[a]	3.3[a]	0[a]	0[a]

† The same letters within a column in the same year and location are not statistically different.
* Tuber samples taken from the Brnik location in 2002 were mixed up and could not be analysed.

4 DISCUSSION

We determined that, at the 90 cm IRW, market yields are higher in the years with sufficient rainfall during the period of growth. When these conditions are met, plants completely cover the inter-row space. Year 2003 was the driest in the last 200 years, which is why we can not make any realistic conclusions on market yield at both IRW in the drought period. The cross-sectional area of the ridge exceeding 1000 cm^2 at the 90 cm IRW allows

a good soil covering of tubers in the ridge. This is why, at this IRW, the yield of green tubers is lower than at the 75 cm IRW. The hollow heart and blackspot disorders affecting the tubers are more dependent on the cultivar and the meteorological conditions during the period of growth than the IRW. Particularly sensitive to hollow heart are thick tubers like the Agria cultivar, especially in the years with abundant rainfall. Blackspot occurs predominantly in the Bright cultivar, in the years of high average temperatures and a lack of rainfall. In Slovenia, other medium-late and late potato cultivars are also in use. These are planted predominantly at the 66 cm and the 70 cm IRWs, which is why a long-term trial involving the cultivation of those cultivars at the 75 cm and the 90 cm IRWs should be carried out. The field trial would provide even clearer insight on the subject.

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