Asian Journal of Crop Science

ISSN 1994-7879

science alert
http://www.scialert.net

ANSInet
an open access publisher
http://ansinet.com

Asian Journal of Crop Science 5 (1): 24-32, 2013
ISSN 1994-7879 / DOI: 10.3923/ajcs.2013.24.32

Combined Effect of Plant Spacing and Time of Earthing up on Tuber Quality Parameters of Potato (*Solanum tuberosum* L.) at Degem District, North Showa Zone of Oromia Regional State

Tesfaye Getachew, Derbew Belew and Solomon Tulu
Department of Horticulture and Plant Sciences, Jimma University College of Agriculture and Veterinary Medicine, P.O. Box 307 Jimma, Ethiopia

Corresponding Author: Solomon Tulu, Department of Horticulture and Plant Sciences, Jimma University College of Agriculture and Veterinary Medicine, P.O. Box 307 Jimma, Ethiopia

ABSTRACT

To investigate the effect of plant spacing and time of earthing up on tuber quality of Jalene potato variety four levels of plant spacing (10, 20, 30 and 40 cm) and four times of earthing (15, 30, 45 days after plant emergence and no earthing) were combined (4×4) in Randomized Complete Block Design (RCBD). Data collected on tuber quality parameters were subjected to analysis of variance. Significantly the highest number of green potatoes (41 tubers/plot) was observed at the interaction of 10 cm with no earthing up whereas the highest number of large tubers (6 tubers/hill) was found at the interaction of 40 cm with earthing up after 15 days. The effect of plant spacing was highly significant on all tuber quality parameters studied: Number of small, medium, large and green tubers, tuber dry matter and specific gravity. For majority of tuber quality parameters 40 and 30 cm were preferable while significantly the highest tuber dry matter (21.53 %) and specific gravity (1.082) was found at 30 cm. The effect of time of earthing up was highly significant on all tuber quality parameters studied: number of medium, large and green tubers except number of small tubers, tuber dry matter and specific gravity. Most tuber quality parameters showed superior performance at earthing up of 15 days. Therefore, 30 cm plant spacing and earthing up at 15 days after complete plant emergence can be used at the study area, for the production of potato with improved and better tuber quality.

Key words: Potato (*Solanum tuberosum* L.), plant spacing, time of earthing up, tuber dry matter content, tuber quality parameters

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family Solanaceae, genus *Solanum* and section *Tuberarium* (Correll, 1962). Its history begins about 8,000 years ago near Lake Titicaca which is located at 3800 m.a.s.l. in the Andes mountain range of South America on the border between Bolivia and Peru (FAO, 2008). Potato is one of the tuber crops and has important impact on human feeding in terms of high yield per unit area, energy and protein, in which it is superior to wheat and rice. Among the root and tuber crops, potato ranks first in volume of production and consumption, followed by cassava, sweet potato and yam. In the world potato is grown in 79% of the countries in the world (FAO, 2008). Production and the demand for potatoes in Asia, Africa and Latin America have dramatically increased and the production raised from less than 30 million tons

in the early 1960s to more than 165 million tons in 2007 (FAO, 2008). Potato production in the developing countries exceeded the industrial states for the first time in 2005. China is the largest potato producer and nearly one third of all potato is harvested in China and India (FAO, 2008). Potato has been introduced to Ethiopia in 1859 by a German Botanist called Schimper (Berga *et al.*, 1994). The country has about 70% of the available agricultural land suitable for potato production (Gebremedhin *et al.*, 2008). Even though the country is endowed with suitable climatic and edaphic conditions for potato production the national average yield is about 8.2 tons ha^{-1} which is very low as compared to the world's average production of 17.67 tons ha^{-1} (FAO, 2008). The low yield of potato in the country is attributed to factors such as poor agronomic practices, lack of sustainable supply of improved planting material, high cost of seed tubers, disease and pest problem and inadequate storage (Bereke, 1994). In Degem woreda (central highlands of Ethiopia), farmers even produce less than the national average. One of the bottle neck problems for production of potato with better tuber quality is lack of information on the appropriate agronomic practices, since no research has so far been conducted for the area to determine the optimum plant spacing and time of earthing up for optimum production of potato with better tuber quality. It is well known that plant spacing can alter above and below ground biomass accumulation of vegetable crops. Thus, any plant spacing variation could influence biomass accumulation and subsequently tuber number (Santos and Gilreath, 2004). Earthing up in potatoes is a common and an important agronomic practice. It involves drawing mounds of soil up around the plant to prevent new tubers from growing and turning green and poisonous. It also helps to prevent greening, tuber moth and blight infection. It also helps to loosen the subsoil for good aeration and/or to cover the tubers with sufficient layer of soil. Therefore, the present study was conducted to determine the effect of plant spacing and time of earthing up on potato tuber quality.

MATERIALS AND METHODS

The experiment was conducted at Degem District, North Showa Zone of Oromia regional state during 2010/2011 main cropping season. Boneya kebele is the specific place for the experiment and it is one of the major potato producing kebeles and 15 km far from the Degem District capital. Degem District; part of the central highlands of the country is located 124 km away from Addis Ababa, on the way to Gojjam. It is located at about 38°29' to 38°44' East longitude and 9°34' to 10°03' North latitude. The area is with an elevation of 2878 m.a.s.l., receiving an annual rainfall of 900-1400 mm, with the mean annual minimum and maximum temperature of 15 and 22°C, respectively and has a sandy loam soil (Anonymous, 2011). Potato variety Jalene, obtained from Holleta Agricultural Research Center, was used for the experiment since it is one of the potential potato cultivars for the central highlands of Ethiopia such as Degem District. In this experiment four different levels of plant spacing including 10, 20, 30 and 40 cm between plants per each row and four times of earthing up such as earthing up after 15 days, 30 days and 45 days of complete emergence of potato plants and no earthing up as a control treatment were combined in 4×4 factorial arrangements in Randomized Complete Block Design (RCBD) with three replications. Each of the sixteen treatment combinations was put on an experimental plot of 9 m^2 (3 m length×3 m width). A distance of 0.75 m between the plots within a block and 1 m distance between replications was used for this experiment. Potato variety, Jalene was selected as a planting material for its high yield, tuber color and cooking quality. Well sprouted tubers of 45-50 g weight were selected and planted at 12 cm depth. Phosphorus was applied at the time planting at the rate of 195 kg DAP ha^{-1} and nitrogen was also applied in a split, first banded at planting and then side dressed

after full emergence at a rate of 165 kg UREA ha^{-1} (EARO, 2004). For earthing up soil was uniformly put around the plant up to 20 cm height and 15 cm top width at the different times of earthing up except the control. Other agronomic practices were done as per the recommendation (Gebremedhin *et al*., 2008). To investigate the influence of plant spacing and time of earthing up on potato tuber quality, data were collected for tuber size category, number of green potato tubers, tuber dry matter and tuber specific gravity per plot basis, checked for meeting all the ANOVA assumptions and subjected to analysis of variance (Montogomery, 2005) of the GLM procedure for factorial, Randomized Complete Block Design (RCBD) of SAS Version 9.2 statistical software (SAS Institute Inc., 2002). Treatment means were separated by using LSD value at 5% significance level (Montogomery, 2005).

RESULTS AND DISCUSSION

The effect of both plant spacing and time of earthing up was highly significant ($p<0.001$) on all potato tuber quality parameters studied including tuber size categories such as number of medium and large potato tubers and number of green potato tubers except number of small potato tubers, tuber dry matter content and tuber specific gravity which were only significantly affected by plant spacing.

Tuber size categories

No. of small tubers: Significantly the highest number of small tubers (5.50) was obtained at the closer plant spacing of 10 cm, whereas the lowest number of small potato tubers (2.16) was found at the wider plant spacing of 40 cm (Table 1, Appendix Table 1). At closer plant spacing there could be strong competition among plants for resources and reduced photo assimilate production and redistribution to the tubers and finally highest number of small sized tubers produced. Dwelle and Love (1993) also concluded that in closer plant spacing, bulking rates of individual tubers decreased and these resulted in smaller tuber. Similarly Oliveira (2000) reported that more number of small sized tubers was produced by reducing plant spacing.

No. of medium tubers: The highest number of medium sized potato tuber (5.75) was recorded at the closer plant spacing of 20 cm but the lowest number (1.25) was obtained at the closest plant spacing of 10 cm (Table 1). This is due to the presence of higher computation among plants for

Table 1: Means for number of small tubers and number of medium tubers as affected by plant spacing and time of earthing up

	Tuber size category	
Treatments	Small tubers (count/plant)	Medium tubers (count/plant)
Intra-row spacing (cm)		
10	5.50^{a}	1.25^{c}
20	2.42^{b}	5.75^{a}
30	2.25^{b}	3.58^{b}
40	2.16^{b}	3.33^{b}
Time of earthing np (days)		
No earthing up	3.16^{a}	3.00^{b}
15	2.92^{a}	3.92^{a}
30	3.41^{a}	3.58^{ab}
45	2.83^{a}	3.42^{ab}
LSD (5%)	0.47	0.59
CV (%)	18.45	20.63

Means with different letters per column differ significantly at $p<0.05$ as established by LSD test

resources in the narrowest intra row spacing that leads to production of lower medium sized tubers. The current result is in line with the work of Essah *et al.* (2004) who concluded that high number of medium sized tuber was produced in the closer (15-22.5 cm) plant spacing. In case of earthing up the highest number of medium sized tuber (3.92) was produced at 15 days earthing up (Table 1). This might be due to the reason that earthing up at 15 days after complete plant emergence created favorable conditions for plant growth and ultimately more number of medium sized tubers produced. This result is similar to the finding of Qadir (1997) and Qadir *et al.* (1999) who confirmed that earthing up at 15 days after complete plant emergence resulted in better plant and yield performance.

No. of large tubers: The highest number of large sized tuber (6.33) was obtained in the interaction between the wider plant spacing of 40 cm and earthing up at 15 days after complete plant emergence (Table 2).

This could be due to the fact that early earthing up during the active growth period of the plant improved the soil conditions for nutrient absorption and also at the wider plant spacing due the presence of minimum competition; plants absorbed the sufficiently available resources and increased their photosynthetic efficiency that ultimately increased the number of large sized tubers. The current result is in consistency with the work of Gulluoglu and Arioglu (2009) who confirmed that, the percentage of large tuber in total tuber yield was increased with widening plant spacing. Similarly Yenagi *et al.* (2003), Essah *et al.* (2004) and Tafi *et al.* (2010) also reported that the production of large tubers increased in the wider plant spacing due to less competition for nutrients and moisture compared to the closer plant spacing. Qadir (1997) and Qadir *et al.* (1999) also confirmed that earthing up at 15 days after complete plant emergence resulted in better yield and overall plant performance.

Table 2: Means for number of large tubers as affected by interaction effect of plant spacing and time of earthing up

Plant spacing×time of earthing up	No. of large sized tuber (count /plant)
10 cm plant spacing×no earthing up	0.00^{f}
10 cm plant spacing×earthing up after 15 days	0.67^{f}
10 cm plant spacing×earthing up after 30 days	0.33^{f}
10 cm plant spacing×earthing up after 45 days	0.00^{f}
20 cm plant spacing×no earthing up	0.67^{f}
20 cm plant spacing×earthing up after 15 days	0.33^{f}
20 cm plant spacing×earthing up after 30 days	0.67^{f}
20 cm plant spacing×earthing up after 45 days	0.67^{f}
30 cm plant spacing×no earthing up	3.67^{e}
30 cm plant spacing×earthing up after 15 days	6.00^{ab}
30 cm plant spacing×earthing up after 30 days	4.33^{cde}
30 cm plant spacing×earthing up after 45 days	4.00^{de}
40 cm plant spacing×no earthing up	4.00^{de}
40 cm plant spacing×earthing up after 15 days	6.33^{a}
40 cm plant spacing×earthing up after 30 days	5.33^{abc}
40 cm plant spacing×earthing up after 45 days	5.00^{bcd}
LSD (5%)	0.52
CV (%)	23.88

Means followed by different letters per column differ significantly at $p<0.05$ as established by LSD test

No. of green tubers: The highest number of green potato (41 tubers per plot) was obtained at the interaction effect between the closer plant spacing of 10 cm and no earthing up. However, the lowest number of green potatoes (5 tubers per plot) was found at the interaction between the wider plant spacing of 30 and 40 cm with earthing up at 15 days after complete plant emergence (Appendix Table 2).

Time of earthing up showed significant differences in the number of green potatoes under the same plant spacing (Fig. 1) indicating that the effect of different times of earthing up is different for the different plant spacing treatments. This could be due to the combined effect of plant spacing and earthing up in that at the closer plant spacing there could be smaller sized but high number of potato tubers and also due to the absence of earthing up the tubers are exposed to light and ultimately the number of green potatoes increased. On the other hand at the wider plant spacing there could be larger sized but small number of potato tubers and due to earthing up at 15 days after complete plant emergence the tubers are not exposed to light that finally reduced the number of green potatoes. Qadir *et al.* (1999) and Qadir (1997) also found minimum number of green potatoes at 15 days earthing up after complete plant emergence. In similar manner Rani (2011) also

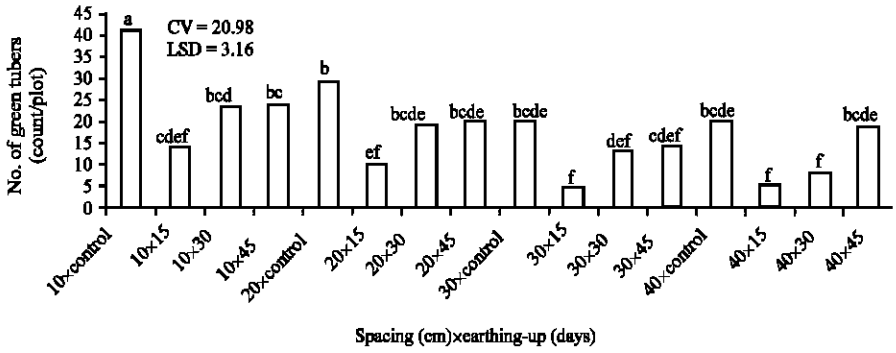

Fig. 1: Means for number of green potato tubers per plot as influenced by the interaction between plant spacing and time of earthing up. Means for number of green potato tubers followed by different letters (without a common superscript) per plot differ significantly at $p<0.05$ as established by LSD test

Table 3: Means for tuber dry matter content, specific gravity, as affected by plant spacing and time of earthing up

Treatments	Tuber dry matter content (%)	Tuber specific gravity (g cm^{-3})
Intra-row spacing (cm)		
10	19.57^{c}	1.071^{b}
20	21.08^{b}	1.080^{a}
30	21.53^{a}	1.082^{a}
40	19.62^{c}	1.072^{b}
Time of earthing np (days)		
Control	20.46^{a}	1.076^{a}
15	20.40^{a}	1.076^{a}
30	20.43^{a}	1.077^{a}
45	20.52^{a}	1.076^{a}
LSD (5%)	0.33	0.002
CV (%)	1.94	0.22

Means followed by different letters per column differ significantly at $p<0.05$ as established by LSD test

reported that early earthing up after 15 days after complete plant emergence reduced the percentage of green potato tubers. In similar investigation Tafi *et al.* (2010) indicated that earthing up decreased greening of tuber compared to no earthing up.

Dry matter content: The highest dry matter content (21.53 %) was recorded at the wider plant spacing of 30 cm while the lowest dry matter content (19.57 %) was recorded at the closer plant spacing of 10 cm which is at par with dry matter content recorded at the wider plant spacing of 40 cm (Table 3).

In the closer plant spacing due to competition for light and other important resources, the photosynthetic rate of plants and ultimately the dry matter partitioning to the tuber is reduced. Similarly in the widest plant spacing due to the presence of minimum competition the vegetative growth of plants extended and consumed high dry matter produced and thus, the ratio of dry matter partitioning to the underground part (tuber) is reduced. Burton (1989), Tamiru (2004) and Zaag *et al.* (1990) also reported highest dry matter accumulation in plants grown at the wider plant spacing. Tafi *et al.* (2010) also indicated that in the closer plant spacing, competition for resources among plants in the later growing period resulted in significant losses of tuber dry matter content.

Specific gravity: The highest tuber specific gravity (1.082) was obtained at the wider plant spacing of 30 cm whereas the lowest tuber specific gravity (1.071) was recorded at the closer plant spacing of 10 cm which is at par with tuber specific gravity recorded at the wider plant spacing of 40 cm (Table 3). In the closer plant spacing due to the presence of higher competition among plants, there could be nutrient and other resources scarcity that reduced tuber specific gravity while in the wider plant spacing there could be excessive utilization of nutrient per individual plant that decreased the tuber specific gravity. Henery (2005) also reported lower specific gravity in plants grown at closer plant spacing. In similar investigation, Zebarth *et al.* (2006) also confirmed that tuber specific gravity decreased at the closer plant spacing. But in the widest plant spacing of 40 cm due to the presence of minimum competition the vegetative growth period of plants extended and consumed the highest quantity of dry matter produced and thus, the ratio of dry matter partitioning to the underground part (tuber) is reduced and this in turn resulted in the lowest tuber specific gravity.

CONCLUSION

The result of the current study indicated that both plant spacing and time of earthing up significantly affected all potato tuber quality parameters studied including tuber size categories such as number of medium and large potato tubers and number of green potato tubers but number of small potato tubers, tuber dry matter content and tuber specific gravity were only significantly affected by plant spacing. This study further indicated the combined effect of plant spacing and time of earthing since the interaction effect of plant spacing and time of earthing up was observed on the number of green potatoes and number of large sized potato tubers. Significantly the highest number of green potatoes (41 tubers/plot) and lowest number of large sized tubers (0 tubers/hill) was recorded at the interaction of 10 cm plant spacing and no earthing up whereas the lowest number of green potatoes (5 tuber/plot) and the highest number of large sized potatoes (6 tubers/hill) was recorded at the interaction effect of 40 cm plant spacing and earthing up after 15 days of complete plant emergence. The current experiment showed that plant spacing significantly affected tuber dry matter content (%), tuber specific gravity, number of green potatoes

and tuber size categories. The highest value of potato tuber quality parameters such as dry matter content (21.53%) and tuber specific gravity (1.082 g cm^{-3}) was observed in 30 cm plant spacing. Similarly, time of earthing up significantly affected number of green potatoes, number of medium sized tubers and number of large sized tubers. Superior performance in most potato tuber quality parameters was observed at earthing up after 15 days of complete plant emergence. It can be concluded from this study that for the majority of the potato tuber quality parameters 30 cm plant spacing and earthing up after 15 days of complete plant emergence are preferable. The result of this study verified that potato tuber quality was influenced by plant spacing and time earthing up. Therefore, 30 cm plant spacing in combination with earthing up at 15 days after complete plant emergence can be used for better and improved tuber quality of potato variety Jalene on the sandy loam soil of Degem district, under rain fed condition.

ACKNOWLEDGMENTS

We would link to thank the North Showa Zone Agriculture and Rural Development Office (ARDO) for all rounded support provided during our research work. Our special gratitude is extended to the Rural Capacity Building Project (RCBP) for sponsoring our research work. We gratefully acknowledge the immense contributions made by Jimma University College of Agriculture and Veterinary Medicine postgraduate coordination office for their facilitation and fruitful guidance during the research work and for providing research and computer facilities.

APPENDIX

Appendix Table 1: Mean square values for number of small tubers, number of medium tubers and number of large tubers

		Mean squares		
Source of Variation	df	No. of small tubers	No. of medium tubers	No. of large tubers
Block	2	0.15	1.27	0.43
Intra row sp.	3	31.27*	40.63**	79.14**
Earthing up	3	0.83^{ns}	1.74**	3.36**
Sp.×Earthing up	9	0.15^{ns}	0.76^{ns}	1.00*
Error	30	0.32	0.52	0.39
SE±		0.56	0.72	0.63
CV		18.45	20.63	23.88

*: Significant, **: Highly significant, Ns: Non significant, df: Degree of freedom

Appendix Table 2: Mean square values for number of green potatoes, dry matter content and specific gravity

		Mean squares		
Source of variation	df	NGP	DMC	SG
Block	2	10.68	0.25	0.000009
Intra row sp.	3	440.57**	12.15**	0.0004**
Earthing up	3	723.74**	0.02^{ns}	0.000003^{ns}
Sp.×Ear thing-up	9	31.78*	0.15^{ns}	0.000004^{ns}
Error	30	14.35	0.16	0.000006
SE±		3.79	0.39	0.0023
CV		20.96	1.95	0.22

*: Significant, **: Highly significant, Ns: Non significant, df: Degree of freedom, NGP: No. of green potato, DMC: Dry matter content, SG: Specific gravity

REFERENCES

Anonymous, 2011. Degem woreda profile. Oromiya National Regional State. http://www.oromiyaa.com/english/index.php?option=com_content&view=article&id=217&Itemid=559

Bereke, T.T., 1994. The utilization of True Potato Seed (TPS) as an alternative method of potato production. Ph.D. Thesis, School of Graduate Studies of Wageningen University, Wageningen.

Berga, L., W. Gebremedhin, J. Teresa and T.T. Bereke, 1994. Potato agronomy research in Ethiopia. Proceedings of the 2nd National Horticultural Workshop, December 2-3, 1994, Institute of Agricultural Research, Addis Ababa, Ethiopia, pp: 101-109.

Burton, W.G., 1989. The Potato. 3rd Edn., Longman Scientific and Technical Publisher, Exssex UK, pp: 72.

Correll, D.S., 1962. The Potato and its Wild Relatives: Section Tuberarium of the Genus Solanum. Texas Research Foundation, Texas, USA., Pages: 606.

Dwelle, R.B. and S.L. Love, 1993. Potato Growth and Development. APS Press, St. Paul, MN., USA.

EARO, 2004. Directory of released crop varieties and their recommended cultural practices. Ethiopian Agricultural Research Organization, Addis Abeba, Ethiopia.

Essah, S.Y.C., D.G. Holm and J.A. Delgado, 2004. Yield and quality of two U.S. red potatoes influence of nitrogen rate and plant population. Proceedings of the 4th International Crop Science Congress, September 26-October 1, 2004, Brisbane, Australia.

FAO, 2008. International year of potato. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.potato2008.org/en/index.html

Gebremedhin, W.G., G. Endale and L. Berga, 2008. Root and Tuber Crops. EIAR. Addis Ababa, Ethiopia.

Gulluoglu, L. and H. Arioglu, 2009. Effects of seed size and in-row spacing on growth and yield of early potato in a Mediterranean-type environment in Turkey. Afr. J. Agric. Res., 4: 535-541.

Henery, M., 2005. Specific gravity of potatoes. Department of Agriculture and Food. Manjimup Horticultural Research Centre, Western Australia, Australia.

Montogomery, D.C., 2005. Design and Analysis of Experiments. 6th Edn., John Wiley and Sons, inc., USA, Pp: 97-203.

Oliveira C.A.D.S., 2000. Potato crop growth as affected by Nitrogen and plant density. Pesq. Agropec. Bras., 35: 939-950.

Qadir, G., 1997. Effect of earthing-up at different stages of growth on yield of different potato cultivars under the soil and climatic conditions of Peshawar. Crop Husbandry Section of Pakistan, Pashawar, Pakistan.

Qadir, G., M. Ishtiaq and I. Ali, 1999. Effect of earthing-up at different stages of growth on yield of potato cultivar cardinal under the soil and climatic conditions of Peshawar (Pakistan). Sarhad J. Agric., 15: 423-425.

Rani, S., 2011. Best agricultural techniques for successful potato production in India. http://agrimantra.blogspot.com/2011/10/best-agricultural-techniques-for.html

SAS Institute Inc., 2002. SAS User's Guide, Version 9.2. SAS Institute Inc., Cary, NC., USA.

Santos, B.M. and J.P. Gilreath, 2004. Influnce of in-row distance on potato (*Solanum tuberosum* L.) seed yield and economic feasibility. Gulf Coast Research and Education Center, University of Florida, USA.

Tafi, M., S.A. Siyadat, R. Radjabi and M. Majadam, 2010. The effect of earthing up on the potato yield in Dezful (Khouzestan, Iran) weather condition. Middle East J. Sci. Res., 5: 392-393.

Tamiru, H., 2004. Effect of plant population and harvesting time on tuber yield of potato crop. Ethiopia J. Biol. Sci., 4: 1-9.

Yenagi, B.S., S.S. Meli and S.S. Angadi, 2003. Effect of row spacing, planting date and nitrogen level on tuber grade, yield and economics of potato. Karnataka J. Agric. Sci., 17: 220-223.

Zaag, P.V., A.L. Demagante and E.E. Ewing, 1990. Influence of plant spacing on potato (*Solanum tuberosum* L.) morphology, growth and yield under two contrasting environments. Potato Res., 33: 313-323.

Zebarth, B.J., W.J. Arsenault and J.B. Sanderson, 2006. Effect of spacing and N fertilizer use efficiency parameters of two potato cultivars. Am. J. Potato Res., 83: 289-296.