African Crop Science Journal, Vol. 23, No. 3, pp. 295 - 304
ISSN 1021-9730/2015 $4.00

INFLUENCE OF TREATMENT OF SEED POTATO TUBERS WITH PLANT CRUDE ESSENTIAL OIL EXTRACTS ON PERFORMANCE OF THE CROP

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(Received 5 March, 2015; accepted 20 August, 2015)

ABSTRACT

Farmers in most developing countries store seed potato (*Solanum tuberosum* L.) tubers in traditional storage that invariably leads to rapid deterioration in the quality of the seed tubers due to sprouting and aging. Thus, potato seed tubers senesce and are past their prime when planted. A pot experiment was conducted at Sirinka Agricultural Research Centre, in north-eastern Ethiopia, to evaluate the effect of treating seed potato tubers with crude plant essential oil extracts, on the growth and yield of the potato crop. Treatments consisted of seed potato tubers treated with dill weed, spearmint, black cumin and eucalyptus crude essential oil extracts, each applied at 45, 90 and 135 mg kg^{-1} of potato tubers for one month, plus a control treatment. The control consisted of untreated tubers. Results revealed that potato plants grown from seed tubers treated with oil extracts from dill weed, spearmint, and eucalyptus at 135 mg kg^{-1}, took the longest time to sprout, flower, and tubers to mature. Potato plants grown from seed tubers treated with dill weed, spearmint, black cumin and eucalyptus crude essential oil extracts at 135 mg kg^{-1} were 23 - 38% taller than plants from the untreated seed tubers. Similarly, potatoes from these treatments had 21 - 89% more numbers of leaves compared to plants from the untreated seed tubers. Crude essential oils from dill weed at the concentrations of 90 and 135 mg kg^{-1} and eucalyptus at 135 mg kg^{-1}, had the greatest positive effects on growth and yield of the potato crop.

Key Words: Black cumin, dill weed, eucalyptus, *Solanum tuberosum*

RÉSUMÉ

Dans plusieurs pays en développement, les paysans conservent les tubercules de pomme de terre (*Solanum tuberosum* L.) en stockage traditionnel, ce qui est responsable de la détérioration rapide de la qualité des semences due au vieillissement et au bourgeonnement des tubercules. Alors, les tubercules de pomme de terre vieillissent et perdent leur fraîcheur avant d'être planté. Une expérimentation en pots a été conduite au Centre de Recherche Agricole de Sirinka au North-Est de l'Ethiopie pour évaluer l'effet du traitement des tubercules de pomme de terre avec des huiles essentiels sur la croissance et le rendement la culture subséquente. Les traitements consistaient en l'utilisation des huiles essentielles de la fenouille, la menthe verte, du cumin noir et de l'eucalyptus à différente concentrations (45, 90 et 135 mg kg^{-1}) pour traiter les tubercules de pomme de terre pendant un mois, et un traitement témoin (tubercules non traités). Les résultats ont montré que les plants de pomme de terre traités à l'huile essentielle de fenouille, menthe verte, et eucalyptus à 135 mg kg^{-1} ont le plus retardé le bourgeonnement, la floraison, et la maturation des tubercules. Les plants de pomme de terre cultivés après traitement à l'huile essentielle de fenouille, menthe verte, cumin noir et eucalyptus à 135 mg kg^{-1} étaient 23 à 38% plus grands que les plants provenant de tubercules non traitées. De la même façon, les plants traités avaient 21 à 89% plus de feuilles que les plants non traités. Les huiles essentielles de fenouille à 90 et 135 mg kg^{-1} et de l'eucalyptus à 135 mg kg^{-1} ont entrainé une croissance plus accrue et un rendement plus élevé de la culture subséquente de pomme de terre.

Mots Clés: Cumin noir, fenouille, eucalyptus, *Solanum tuberosum*

INTRODUCTION

High quality seed tubers are crucial for potato (*Solanum tuberosum* L.) growers to achieve good yields. High quality seed tubers must be certified, free from seed-borne diseases, decay, firm and physiologically young, as well as free from stress (WPC, 2003; Oliveira *et al*., 2012). One of the most important physiological factors associated with seed potato tuber performance is physiological aging. As a seed tuber ages, it tends to have a shorter dormancy period, emerges earlier, produces multiple stems, initiates tubers earlier at a lower leaf area index, produces less vine growth, senesces earlier, and produces more but smaller tubers (Rehman *et al*., 2001; Olsen and Hornbacher, 2002).

In Ethiopia, farmers store tubers harvested in September or October for a long period until planting in June, which leads to aged, degenerated and diseased tubers (Alemu *et al*., 2012). With seed tuber aging, the sprouts may also develop multiple branches and the tuber may dehydrate significantly. In fact, planting a senile tuber with multiple branches results in failure of plant emergence or weak plants, with many stems and poor tuber yield (FAOSTAT, 2010).

Studies done in Ethiopia, Kenya and Uganda confirmed that through the use of diffused light storage, seed potatoes with strong sprouts can be obtained eventually contributing to high potato yield (Mulatu *et al*., 2005; Gildemacher *et al*., 2009). However, since the dry season is long (6 to 8 months), and the rains come late the next growing season, harvested seed tubers become over-sprouted and aged.

Planting senescent and aged seed tubers is a recipe for low tuber yield and quality since the plants initiate tubers earlier at a lower leaf area index, with less carbohydrate produced to be partitioned for tuber bulking (Olsen and Hornbacher, 2002).

Some aromatic essential oils inhibit the sprouting of potato tubers (Vaughn and Spencer, 1991); however, this suppressing effect is reversible (Oosterhaven *et al.*, 1993), and thus could be used as a sprout growth regulator of seed potatoes during storage (Vokou *et al*., 1993; Oosterhaven *et al*., 1995; Sorce *et al*., 1997). Hartmans *et al*. (1998) concluded that 'Talent', with S-carvone derived from caraway (*Carum carvi* L.) seed as the active ingredient, could be used during storage as a sprout suppressant for ware potatoes at high dosages, and as a sprout growth regulator for seed potatoes at low dosages.

This study was, therefore, undertaken to evaluate the effect of treating potato seed tubers with plant essential oil extracts on the physiological aging of seed potato tubers and the performance of the potato crop. It is hypothesized that plant essential oil extracts prolong the dormancy of seed potato tubers by suppressing sprouting of the bud, with no impact on the growth and tuber yield of the crop.

MATERIALS AND METHODS

A pot experiment was conducted at the experimental farm of Sirinka Agricultural Research Centre in north-eastern Ethiopia under glasshouse conditions.

The treatments consisted of essential oil extracts from dill weed, spearmint, black cumin, and eucalyptus, each applied at three doses (45, 90 and 135 mg kg^{-1} seed tubers) for thirty days. One control with untreated seed tubers was included.

Freshly harvested medium-sized (39-75 g) potato seed tubers of variety 'Gera' were treated with the plant essential oil extracts in 2 litre plastic jars. Twenty seed potato tubers were placed in each jar. The plant essential oil extracts obtained from Wondogenet Agricultural Research Centre, were pipetted on to filter paper (Whatman No. 9; 18.5 cm diameter; Whatman, Maidstone, Kent, Germany), which was taped inside of the lid of each plastic, at the pre-determined treatment doses.

The jars were lid-sealed and arranged in a completely randomised design, with three replications. The lids of the plastic jars were opened once every 2 days, for a period of 5 minutes, to prevent CO_2 build up inside. Thirty days after applying the treatments, four medium-sized potato seed tubers were randomly selected from each treatment in a jar. The potato seed tubers were stored at ambient storage conditions. Five months after the treatment, the seed tubers were planted in pots.

Top soil (0-20 cm) was collected from five points in a field, four at the corner of the quadrate and one at the centre. The soil samples were collected in a zig-zag pattern, using an auger from a farmland at Sirinka Agricultural Research Centre in north-eastern Ethiopia. The soil was Eutric Vertisol, with a pH of 6.2, and clay loam in texture (SARC, 2011). Soil samples were composited and sieved with a 5-mm sieve. The soil was filled into 5-liter plastic pots. Before filling into the pots, the soil was bulk-fertilised with N at the rate of 120 kg N ha^{-1} (0.20 g pot^{-1}) in the form of urea (46% N); and phosphate at the rate of 92 kg P_2O_5 ha^{-1}(0.15 g pot^{-1}) in the form of TSP (45% P_2O_5). Well composted (4 months) cattle manure (CM) was also applied at the rate of 30 t ha^{-1} (50 g pot^{-1}) three weeks before planting.

A medium-sized potato seed tuber of variety 'Gera' was planted into each pot at the depth of 10 cm, and covered with soil. The potato plants were watered at the interval of four days to keep the moisture content at field capacity.

Days to 50% sprout emergence, flowering, and physiological maturity were recorded. Plant height, number of leaves and stems per plant were also recorded at 90 days after planting (DAP). Harvesting of the potato tubers was done from 10 February to 12 March 2012 depending on time of maturity. After harvesting, tuber weight and number per plant were recorded. Healthy tubers > 25 g were considered as marketable (Struik *et al.*, 1990). Harvest index was determined at physiological maturity, as the ratio of fresh tuber weight to the total fresh biomass produced per plant, and expressed as a percentage. Tubers obtained from each pot were categorised as small (< 39 g), medium (39-75 g) and large (> 75 g) according to Kleinhenz and Bennett (1992).

For determination of dry matter, two potato tubers were randomly selected from each pot, chopped into 1-2 cm cubes, mixed thoroughly using a knife, and two fresh sub-samples each weighing 50 g were taken. Each sub-sample was placed in a paper bag and oven-dried at 70 °C for 48 hr. Each sub-sample was subsequently weighed and the mean recorded as dry weight. Percent dry matter content for each sub-sample was then calculated.

The data on phenology, growth, yield, harvest index, as well as dry matter content were recorded from four plants per pot. Harvest index was determined as the ratio of dry weight of tubers to the fresh biomass of potato crop and expressed as a percentage.

The data were subjected to analysis of variance in the Generalised Linear Model, using SAS programme (SAS, 2003, Institute, Inc., Car., NC, USA, ver. 9.1). Mean separation was done using the Least Significant Difference (LSD) test at 5% level of significance.

RESULTS

Days to emergence. Significant ($P<0.01$) differences in days to sprout emergence were observed across all treatments (Table 1). The days to 50% sprout emergence raised from seed tubers treated with spearmint crude essential oil extract at 45 mg kg^{-1}, as well as black cumin at 90 and 135 mg kg^{-1}, were in statistical parity. Furthermore, plants raised from seed tubers treated with dill weed, as well as eucalyptus crude essential oil extracts at 90 mg kg^{-1} did not show significant ($P>0.05$) differences in days to 50% sprout emergence. Treating seed tubers with dill weed, spearmint and eucalyptus crude essential oil extracts at 135 mg kg^{-1} increased the number of days to 50% sprout emergence. In general, compared to the untreated seed tubers, the number of days required for 50% sprout emergence was increased by 52-200% in response to treating seed tubers with dill weed essential oil (Table 1).

TABLE 1. Effect of source of essential oils and dosage on days to 50% emergence, flowering and maturity of potato in a pot experiment in Ethiopia

Source of essential oils	*Dose (mg kg^{-1})	Days to 50% emergence	Days to 50% flowering	Days to 50% maturity
Control	0	8.33	52.17	95.42
Dill weed	45	13.67	56.33	103.67
	90	20.67	62.33	118.33
	135	25.00	65.67	127.33
Spearmint	45	12.67	55.67	102.00
	90	19.67	60.33	115.67
	135	24.33	64.33	125.33
Black cumin	45	8.33	53.33	96.67
	90	12.33	55.33	98.00
	135	12.67	56.00	100.33
Eucalyptus	45	14.33	56.33	103.67
	90	20.67	62.33	118.33
	135	25.00	65.67	127.33
LSD (0.05)		0.985	1.067	0.985
CV (%)		3.5	1.1	0.5

*Quantity of oil extract applied

Days to flowering. Potato plants grown from potato seed tubers treated with different types of crude essential oil extracts, flowered at significantly ($P<0.01$) different times (Table 1). Plants raised from seed tubers treated with dill weed and eucalyptus crude essential oil extracts at 135 mg kg^{-1} had the longest duration (65.67 days) to attain 50% flowering, followed by plants treated with spearmint crude essential oil extract at the same dose. All the other treatments resulted in significantly lower durations to attain 50% flowering (Table 1).

Days to maturity. Significant ($P<0.01$) differences were observed in the duration required for maturity of potato plants grown from tubers subjected to the different treatments (Table 1). Potato plants grown from seed tubers treated with dill weed and eucalyptus crude essential oil extracts at 135 mg kg^{-1}, matured late, followed by plants from seed tubers treated with spearmint oil extract at the same dose. Potato plants grown from seed tubers treated with black cumin oil, at all doses, matured significantly earlier than those from the other treatments, but later than plants in the control treatment. Treating seed tubers with dill weed oil extract at 45 mg kg^{-1} as well as with eucalyptus essential oil extract at 45 and 90 mg kg^{-1} had no significant ($P>0.05$) effect on days to 50% maturity of the potato plants. Compared to the untreated seed tubers, seed tubers treated with essential oil extracts at 135 mg kg^{-1} produced plants whose maturity was delayed by 5 - 32 days (Table 1).

Plant height. Treating seed tubers with the crude essential oil extracts had a significant ($P<0.01$) effect on the height of potato plants at 90 days after planting (DAP) (Table 2). At 90 DAP, potato plants grown from seed tubers treated with dill weed, spearmint, and eucalyptus plant essential oil extracts applied at 90 and 135 mg kg^{-1} were significantly taller than those grown from seed tubers treated with black cumin as well as those that were grown from seed tubers not treated with the oil extracts.

Leaf number. Treating potato seed tubers with plant essential oil extracts had a significant ($P<0.01$) effect on the number of leaves counted at 90 DAP (Table 2). Potato plants grown from seed tubers treated with spearmint oil at 90 and 135 mg kg^{-1} produced significantly more leaves, followed by potato plants treated with dill weed at 90 and 135 mg kg^{-1}, and black cumin at 135 mg kg^{-1}. At 90 days after planting, the number of leaves produced by potato plants grown from seed tubers treated with plant essential oil extracts at the rate of at 135 mg kg^{-1}, was increased by 21 - 89% over the control treatment (Table 2).

Stem number. The number of stems was significantly ($P<0.01$) influenced by the treatments (Table 2). At 90 DAP, potato plants from seed tubers treated with the essential oil extracts had more stems than those grown from tubers treated with black cumin oil as well as the control treatment.

Tuber number. Treating the seed tubers with plant essential oil extracts had a significant ($P<0.01$) effect on the number of tubers produced per plant (Table 3). The number of tubers produced from potato plants grown from seed tubers treated with dill weed, spearmint and eucalyptus oils at 45 mg kg^{-1} were not significantly different from the control treatment. The maximum tuber number was recorded from potato plants grown from seed tubers treated with dill weed oil applied at 90 and 135 mg kg^{-1}, and eucalyptus at 90 mg kg^{-1}. In general, potatoes grown from seed tubers treated with dill weed, spearmint, black cumin as well as eucalyptus crude essential oil extracts at 135 mg kg^{-1} produced 25 - 49% more tubers than plants that arose from the untreated control (Table 3).

Tuber yield. Treating seed tubers with the essential oil extracts had a significant ($P<0.01$) effect on tuber yield per plant (Table 3). The highest tuber yield was obtained from potato plants grown from seed tubers treated with black cumin crude essential oil extracts at the rates of both 90 and 135 mg kg^{-1}. These were closely followed by the tuber yields from seed tubers

TABLE 2. Growth parameters of potato as influenced by seed tuber treatment with plant essential oil extracts at 90 days after planting (DAP) in a pot experiment in Ethiopia

Source of essential oils	*Dose (mg kg^{-1})	Plant height (cm)	Leaves per plant	Stems perplant
Control	0	21.36	17.34	1.96
Dill weed	45	23.70	21.67	3.92
	90	28.14	26.33	4.33
	135	29.29	26.83	4.50
Spearmint	45	25.90	19.88	4.17
	90	28.50	30.84	4.33
	135	29.54	32.72	4.25
Black cumin	45	20.28	19.33	2.58
	90	23.34	23.17	3.33
	135	26.33	26.33	3.50
Eucalyptus	45	23.44	21.03	4.33
	90	28.19	20.77	4.33
	135	27.75	20.97	4.50
LSD (0.05)		2.596	2.344	0.808
CV (%)		6.0	5.6	12.5

*Quantity of oil extract applied

TABLE 3. Effect of treating seed tubers with plant essential oil extracts on the yield of potato in a pot experiment in Ethiopia

Source of essential oils	*Dose (mg kg^{-1})	Tuber weight (g plant^{-1})	Tuber number (plant^{-1})
Control	0	160.54	7.48
Dill weed	45	168.63	7.33
	90	248.39	10.22
	135	251.72	11.12
Spearmint	45	182.41	7.56
	90	195.28	8.81
	135	200.78	9.43
Black cumin	45	164.96	8.75
	90	199.00	9.25
	135	204.26	9.58
Eucalyptus	45	177.53	8.17
	90	220.67	9.83
	135	235.77	9.33
LSD (0.05)		11.077	1.307
CV (%)		3.3	8.7

*Quantity of oil extract applied

treated with eucalyptus crude essential oil extract applied at the rate 135 mg kg^{-1}. The lowest tuber yield was obtained from potato plants grown from seed tubers treated with crude essential oil extracts from dill weed and black cumin both at the rate of 45 mg kg^{-1}, and the control (Table 3).

Tuber size and distribution. Treating seed tubers with plant essential oil extracts significantly ($P<0.01$) influenced the proportion of small-sized (<39 g) and medium-sized (39-75 g) tubers (Table 4). No large-sized tuber was produced. The highest proportions of small-sized tubers were produced by potato plants from seed tubers treated with black cumin crude essential oil extracts at 90 and 135 mg kg^{-1}. The lowest proportions of small-sized tubers were produced by potato plants from seed tubers treated with dill weed at the rate of 90 mg kg^{-1} and those established from the untreated seed tubers (Table 4).

Correlation among growth and yield attributes. Plant height, leaf number, and stem number were significantly ($P<0.05$) and positively correlated with each other and with number and weight of tubers. Tuber weight had a significant and positive correlation with stem number ($r = 0.56^{***}$), plant height ($r = 0.73^{***}$) and leaf number ($r = 0.38^{*}$) (Table 5).

Harvest index (HI) and dry matter content of potato were not affected by the seed potato tuber treatment in this study (data not shown).

DISCUSSION

Phenology and growth parameters. All plant essential oil extracts affected sprout emergence in a dose-dependent manner (Table 1). Early sprout emergence for the untreated potato seed tubers may be due to hastened physiological aging of the seed tubers by suppressing apical meristems. Late sprouting of seed tubers treated with higher doses of the plant essential oil extracts could be attributed to the active roles the volatile chemicals contained in the crude oils such as S-(+)-carvone in dill weed (Song, 2009), R-(-)-carvone in spearmint (Hartmans *et al.,* 1995; Teper-Bamnolker *et al.*, 2010), citronella and citronellol in eucalyptus (Batish *et al.*, 2005), may

TABLE 4. Tuber size distribution of potato as influenced by seed tuber treatment with plant essential oil extracts in a pot experiment in Ethiopia

Source of essential oils	*Dose (mg kg^{-1})	Proportion of small sized tubers (%) (< 39 g)	Proportion of medium sized tubers (%) (39-75 g)
Control	0	41.84	57.22
Dill weed	45	58.10	43.10
	90	43.00	59.98
	135	49.52	55.86
Spearmint	45	59.78	40.43
	90	57.65	42.35
	135	60.78	39.22
Black cumin	45	55.13	44.87
	90	63.98	36.02
	135	63.36	36.64
Eucalyptus	45	56.72	43.28
	90	52.48	47.52
	135	57.83	42.17
LSD (0.05)		2.978	5.82
CV (%)		3.2	7.7

*Quantity of oil extract applied

TABLE 5. Pearson's simple correlation coefficient among growth and yield attributes of potato

	Plant height	Leaf number	Stem number	Tuber number	Tuber weight	Small sized tuber	Medium sized tuber
Plant height							
Leaf number	0.62^{***}						
Stem number	0.66^{***}	0.48^{**}					
Tuber number	0.53^{***}	0.39^{**}	0.35^{*}				
Tuber weight	0.73^{***}	0.38^{*}	0.56^{***}	0.77^{***}			
Small-sized tuber	0.004^{ns}	0.23^{ns}	0.19^{ns}	-0.14^{ns}	-0.23^{ns}		
Medium-sized tuber	0.08^{ns}	-0.15^{ns}	-0.06^{ns}	0.26^{ns}	0.33**	-0.93^{***}	

*,** and *** significant at P < 0.05, 0.01 and 0.001 probability level, respectively; ns: non-significant

have played in suppressing the natural dormancy breakage. The early sprouting of tubers that received low doses of the plant essential oil extracts may be due to the fact that the concentrations of the plant essential oil extracts applied were lower than the threshold level required for delaying sprouting (Hartmans *et al.*, 1998). Since the sprout suppression effect of plant essential oil extracts is reversible (Song, 2009), as the S-(+)-carvone, R-(-)-carvone, citronella and citronellol contained in the essential oil are volatile in nature (Hartmans *et al.*, 1998; Batish *et al.*, 2005), sprouting would be resumed somehow later resulting in delayed sprout emergence.

Information on the specific roles of plant essential oil extracts or their major compounds on flowering and maturity is not available, but the present finding suggests that late emergence of potato seed tuber sprouts in response to the treatment with plant essential oil extracts could be attributed to the roles that volatile chemicals, such as S-(+)-carvone, R-(-)-carvone, citronella and citronellol contained in the oil extracts, play in prolonging vegetative growth, leading to delayed flowering and maturity.

Seed potato tubers treated with dill weed and spearmint essential oil extracts produced taller potato plants and more leaves than other treatments (Table 2). The analysis on emergence time showed that seeds exposed to dill weed and spearmint oils had delayed emergence (Table 1); however, according to the results collected on plant height and number of leaves, the delay did not seem to have adverse effect on the growth of the plants. Potato plants grown from untreated seed tubers took short period to emerge (Table 1), but early senescence (Table 2). This observation agrees with Hartmans *et al.* (1998) who explained that with S-carvone derived from caraway and dill weed seed as the active chemicals, treated seed potatoes started with a delay in plant development, but afterwards compensated with a delay in plant senescence.

Tuber number and yield. The increased tuber number and yield response to the treatments (Table 3) imply that the plant essential oil extracts positively affect the physiology of the tubers to enhance productivity of the potato plants emerging from them. This might be possible through various effects of the plant essential oil extracts on the growth and development of the potato crop. For example, the suppression of apical dominance may have allowed the development of lateral buds, which naturally give rise to many sprouts on the treated seed tubers. This may have led to the production of more stems per plant for the treated seed tubers compared to the untreated ones. This is corroborated by the positive and highly significant ($r = 0.56^{***}$) correlation between stem number and tuber weight.

The higher stem numbers may have led to the production of more potato tubers since potato stem number and yield are closely related (Delaplace *et al.*, 2008; Salimi *et al.*, 2010; Shayanowako *et al.*, 2014). This suggestion concurs with the findings of several researchers who reported that physiologically young and multi-sprouted tubers produced more vigorous plants that gave higher yields later in the growing period (Haase *et al.*, 2007; Eremeev *et al.*, 2008; Hospers-Brands *et al.*, 2008; Oliveira *et al.*, 2012). Hartmans *et al.* (1998) also earlier reported that potato seed tubers treated with monoterpene S-(+)-carvone produced higher number of leaves and stems than untreated seed tubers and had a prolonged vegetative growth period, which in turn resulted in higher total tuber yields.

The maximum tuber yield, tuber number and proportion of medium-sized tubers, in response to treating seed tubers with the essential oil extracts from dill weed and eucalyptus at higher doses (Tables 3 and 4), indicate the superiority of their oils in enhancing potato growth and yield.

Tuber size distribution. Enhanced proliferation of lateral buds (Table 4) due to the suppression of apical dominance, through application of the essential oils, may have led to the production of enhanced multiple sprouts, and eventually higher numbers of stems. This phenomenon may have resulted in the higher proportions of small and medium- sized tubers as well as absence of large-sized tubers. This proposition is premised on the result of Salimi *et al.* (2010) that exogenous application of gibberellic acid (GA_3) induces removal of apical dominance and increases the number of sprouts per tuber, which subsequently result in small-sized tubers.

On treating seed tubers with S-(+)-carvone, Hartmans *et al.* (1998) found more small-sized (<55 mm diameter) tubers and suggested it to be due to the higher number of stems produced by the treated seed tubers. In agreement with this result, Bussan *et al.* (2007) reported that doubling stem number increased the proportion of undersized tubers by 10%. Previous reports of Struik *et al.* (1990) and Knowles and Knowles (2006) also showed that increasing stem number decreased tuber size since tubers size distribution is determined by the number of stems per plant and number of tubers per stem.

CONCLUSION

This study has demonstrated that treating seed potato tubers with plant essential oil extracts improves most of the desirable growth and yield attributes of potato plants grown from the tubers. The results have also revealed that treating seed tubers with crude essential oil extracts from dill weed at the rates 90 and 135 mg kg^{-1} and from eucalyptus at the rate of 135 mg kg^{-1} has desirable effects on the performance of the potato plants. Therefore, treating potato seed tubers with these essential oils before storage should be used as an effective technology for delaying tuber sprouting, senescence, and aging as well as to enhance growth and yield of the crop.

ACKNOWLEDGEMENT

The authors express gratitude to the Ethiopian Ministry of Education of Government of Ethiopia for funding the research; and Haramaya University for the research funds. The management and staff members of Sirinka Agricultural Research Centre provided logistical and technical support during the pot experiments.

REFERENCES

Alemu Worku, Tekalign Tsegaw and Fentahun Mengistu. 2012. Yield and yield components of potato cultivars as influenced by period of seed tuber storage at Adet. In: Gebremedhin Woldegiorgis, S. Schulz and Baye Berihan (Eds.). Seed potato tuber production and dissemination experiences, challenges and prospects. *Proceedings of the National Workshop on Seed Potato Tuber Production and Dissemination, 12-14 March 2012, Bahir Dar, Ethiopia*.

Batish, D.R., Singh, H.P., Setia, N., Kaur, S. and Kohli, R.K. 2005. Chemical composition and inhibitory activity of essential oil from decaying leaves of *Eucalyptus citriodora.* Verlagder Zeitschriftfür Naturforschung Tübingen. Available on line at http://www.znaturforsch.com Accessed on 6/8/2014.

Bussan, A.J., Mitchell, P.D., Copas, M.E. and Drilias, M.J. 2007. Evaluation of the effect of density on potato yield and tuber size distribution. *Crop Science* 47: 2462-2472.

Delaplace, P., Brostaux, Y., Fauconnier, M.L. and du Jardin, P. 2008. Potato (*Solanum tuberosum* L.) tuber physiological age index is a valid reference frame in postharvest ageing studies. *Postharvest Biology and Technology* 50:103-106.

Eremeev, V., Jõudu, J., Lääniste, P., Mäeorg, E., Selge, A., Tsahkna, A. and Noormets, M. 2008. Influence of the thermal shock and pre-sprouting on potato tuber yield. *Spanish Journal of Agricultural Research* 6(1):105-113.

FAOSTAT (Food and Agricultural Organisation Statistic). 2010. Statistical Database, www.fao.org. Accessed on 2/5/2013.

Gildemacher, P., Kaguongo, W., Ortiz, O., Tesfaye, A., Woldegiorgis, G., Wagoire, W., Kakuhenzire, R., Kinyae, P., Nyongesa, M. and Struik, P. 2009. Improving potato production in Kenya, Uganda and Ethiopia: A system diagnosis. *Potato Research* 52 (2): 173-205.

Haase, T., Schüler, C., Piepho, H.P., Thöni, H. and Heß, J. 2007. The Effect of preceding crop and pre-sprouting on crop growth, N use and tuber yield of main crop potatoes for processing under conditions of N stress. *Journal of Agronomy and Crop Science* 193: 270-291.

Hartmans, K.J., Diepenhorst, P., Bakker, W. and Gorris, L.G.M. 1995. The use of carvone in agriculture - sprout suppression of potatoes and antifungal activity against potato-tuber and other plant-diseases. *Industrial Crops and Products* 4: 3-13.

Hartmans, K.J., Lenssen, J.M. and de Varies, R.G. 1998. Use of Talent (carvone) as sprout growth regulator of seed potatoes and the effect on stem and tuber number. *Potato Research* 41:190-201.

Hospers-Brands, A.J.T.M., Ghorbani, R., Bremer, E., Bain, R., Litterick, A., Halder, F., Leifert, C. and Wilcockson, S.J. 2008. Effects of pre-sprouting, planting date, plant population and configuration on late blight and yield of organic potato crops grown with different cultivars. *Potato Research* 51: 131-50.

Kleinhenz, M.D. and Bennett, M.A. 1992. Growth and yield of potato (*Solanum tuberosum* L.)

cultivars Atlantic and Monona as influenced by seed type and size. *American Potato Journal* 69: 117-129.

Knowles, N.R. and Knowles, L.O. 2006. Manipulating stem number, tuber set, and yield relationships for northern- and southern-grown potato seed lots. *Crop Science* 46: 284-96.

Mulatu, E., Osman, E.I. and Etenesh, B. 2005. Improving potato seed tuber quality and producers' livelihoods in Hararghe, Eastern Ethiopia. *Journal of New Seeds* 7(3): 31-56.

Oliveira, J.S., Moot, D., Brown, H.E., Gash, A. and Sinton, S. 2012. Sprout development of seed potato tuber after different storage conditions. *Agronomy New Zealand* 42: 53-58.

Olsen, N. and Hornbacher, A. 2002. Effects of the season on seed potato physiology and performance. Presented at the Idaho Potato Conference on January 23, University of Idaho, U.S.A. 6pp.

Oosterhaven, K., Hartmans, K.J. and Huizing, H.J. 1993. Inhibition of potato *(Solanum tuberosum)* sprout growth by the monoterpene S-carvone: Reduction of 3-hydroxy-3-methylglutaryl coenzyme A reductase activity without effect on its mRNA level. *Journal of Plant Physiology* 141: 463-469.

Oosterhaven, K., Poolman, B. and Smid, E.J. 1995. S-Carvone as a natural potato sprout inhibiting, fungistatic and bacteristatic compound. *Industrial Crops and Products* 4: 23-31.

Rehman, F., Lee, S.K., Kim, H.S., Jeon, J.H., Park, Ji-Y. and Joung, H. 2001. Dormancy breaking and effects on tuber yield of potato subjected to various chemical and growth regulators under greenhouse conditions. *Journal of Biological Science* 1(90): 818-820.

Salimi, Kh., Tavakkol, A.R., Hosseini, M.B. and Struik, P.C. 2010. Effects of gibberellic acid and carbon disulphide on sprouting of potato mini-tubers. *Scientia Horticulturae* 124: 14-18.

SARC (Sirinka Agricultural Research Centre), 2011. Annual report, May, 2-3, Woldya, Ethiopia.

Shayanowako, A., Mangani, R., Mtaita, T. and Mazarura, U. 2014. Effect of stem density on growth, yield and quality of potato variety amethyst. *African Journal of Agricultural Research* 9(17): 139-1397.

Song, X. 2009. The impact of dill weed, spearmint and clove essential oils on sprout suppression in potato tubers. M.Sc. Thesis, University of Saskatchewan, Saskatoon, SK. Canada.

Sorce, C., Lorenzi, R. and Ranalli, P. 1997. The effects of (S)-(+)-carvone treatments on seed potato tuber dormancy and sprouting. *Potato Research* 40: 155-61.

Struik, P.C., Haverkort, A.J., Vreugdenhil, D., Bus, C.B. and Dankert, R. 1990. Manipulation of tuber-size distribution of potato. *Potato Research* 33(4): 417-432.

Teper-Bamnolker, P., Dudai, N., Fischer, R., Belausov, E., Zemach, H., Shoseyov, O. and Eshel, D. 2010. Mint essential oil can induce or inhibit potato sprouting by differential alteration of apical meristem. *Planta* 232: 179-186.

Vaughn, S.F. and G.F. Spencer, 1991. Volatile monotherpenes inhibit potato tuber sprouting. *American Potato Journal* 68: 821-831.

Vokou, D., Vareltzidou, S. and Katinakis, P. 1993. Effects of aromatic plants on potato storage - sprout suppression and antimicrobial activity. *Agriculture Ecosystems and Environment* 47: 223-35.

WPC (Western Potato Council), 2003. Guide to commercial potato production on the Canadian Prairies. Winnipeg: Western Potato Council. Available on line at www.cfia-acia.agr.ca Accessed on 8/8/2014.