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EFFECTS OF CARAWAY (*Carum carvi* L.) SEED ON SPROUTING OF POTATO (*Solanum tuberosum* L.) TUBERS UNDER DIFFERENT TEMPERATURE CONDITIONS

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ABSTRACT

Effects of different caraway seed treatments (ground (G) and whole seed (W)) and doses (50 g, 100 g, 150 g) on sprouting, sprout length, the number of sprouts per potato tuber and the weight loss of potato tubers were investigated under two different temperatures (8 °C and 15 °C). At 8 °C, ground seed treatments prevented sprouting until day 105. The most effective treatment was chlorpropham (CIPC) to reduce sprout length. The lowest number of sprouts per tuber was observed for ground seed and CIPC treatments. G100 and G150 were the most effective treatments to prevent weight losses at 8 °C. In general, the effects of CIPC treatment were reduced at 15 °C storage temperature. Ground seed treatments were very effective to prevent sprouting at 15 °C. CIPC was the most effective treatment to limit sprout length at the same temperature. Ground seed treatments were the most effective treatments for reducing number of sprouts on potato tubers and preventing weight losses of tubers.

Key words: Caraway seed, chlorpropham, potato, sprouting

INTRODUCTION

Potato tubers could be stored in controlled or rudimentary conditions. Under controlled conditions, both temperature and humidity or either one of them could be controlled whereas under rudimentary conditions, such as store rooms of small farmers or houses; control of humidity and temperature could not be achieved. Respiration of tubers during storage and breakdown of dormancy during storage result in sprouting and loss of nutritive value of tubers (Burton 1966; Suhag et al., 2006). Breakdown of dormancy also leads to physiological aging of tubers resulting in weight and quality losses for fresh market tubers and also leads to yield losses if such tubers are used as seed tubers for planting (Yosuke et al., 2000; Suhag et al., 2006; Katundu et al., 2007). Chlorpropham [CIPC; isopropyl N-(3-chlorophenylcarbamate)] or CIPC/propham (IPC; isopropyl N-phenylcarbamate) mixtures are the most commonly used to prevent sprouting of tubers in many different countries (Kerstholt et al., 1997). CIPC and IPC may leave contaminants on tubers and its use is not suitable for small scale growers and for seed tubers. Therefore, alternative organic sources to prevent tuber sprouting are being investigated (Hartsmans et al., 1995; Baydar and Karadoğan, 1999). S-(+)-Carvone is an organic compound and obtained from caraway seeds it is widely used to prevent sprouting of potato tubers (Hartmans et al., 1995; Oosterhaven et al., 1995). Use of commercial S-(+)-Carvone may not be practical due to its cost and effects on the taste of stored tubers. In addition, usage of S-(+)-Carvone in store rooms requires special arrangements (Coleman et al., 2001). Use of S-(+)-Carvone containing natural sources rather than commercial S-(+)-Carvone could be an alternative way to prevent sprouting during the storage. While these natural products are likely to be less potent than the commercially available compounds, they are also cheaper and more readily accessible. The natural sources of these compounds slowly release active compounds during the storage and they may also contain a wider range of useful bioactive compounds (Elsadr and Waterer, 2005).

The aim of the study was to investigate effects of whole and grounded caraway seed treatments on sprouting and weight loss of potato tubers under two different storage temperature.

MATERIALS AND METHODS

Cultivar Agria tubers were used in the study. Potato plants were grown at the research fields of Suleyman Demirel University in 2008. Potatoes were harvested at October 2008 and stored at 15 C for one month for the curing period. Potato tubers were stored under two different temperature regimes, 8°C and 15°C. The relative humidity of storage rooms were adjusted to 85% humidity within the storage rooms. Twenty potato tubers (~ 4 kg) were used during the study and the tubers were placed in plastic bottles (10 L). Treatments shown in Table 1 were applied to potato tubers within plastic containers.

Caraway seeds were obtained from a field in Sütçüler, Isparta and CIPC (Sigma) was purchased from a commercial supplier. Volatile oil content of seeds was determined via Clevenger apparatus and caraway seeds contained 4.2% volatile oil. Constituents of caraway oil were determined by gas chromatography (GC) and it was found that caraway oil contained approximately 56% S-(+)-Carvone. GC analysis was performed using Auto System Gas Chromotograph fitted with a flame ionizing detector, Shimadzu C-R3A integrator and MN DB-23 (60 m x 0.25 mm, film thickness 0.25 ~m) capillary column. Sample solutions were prepared in n-hexane and oil components were identified by using standards along with the sample.

Commercially available S-(+)-Carvone and CIPC were applied at a rate of 600 ml and 20 g per 1000 kg potato tubers, respectively (IKC-AT/PD 1993; Hartmans et al., 1995). Volatile oil and Carvone amounts for treatments were calculated according to caraway seeds' volatile oil and Carvone contents.

Table 1. Applied treatments, treatment doses, volatile oil amounts and carvone contents of doses used in the experiment.

Treatments		Dose (g)	Volatile oil amount (ml)	Carvone content (ml)
G 50	Ground seed	50	2.1 ml	1.16 ml
G 100	Ground seed	100	4.2 ml	2.31 ml
G 150	Ground seed	150	6.3 ml	3.47 ml
W 50	Whole seed	50	2.1 ml	1.16 ml
W 100	Whole seed	100	4.2 ml	2.31 ml
W 150	Whole seed	150	6.3 ml	3.47 ml
Chlorpropham	CIPC	0.08	-	-
Control		-	-	-

Different doses of whole or ground caraway seeds were used as treatments (1.25, 2.5 and 3.75 kg/100 kg tuber). Tubers were placed in plastic containers and ground and whole caraway seeds were wrapped in cheese cloths and placed on top and a single CIPC treatment was applied to tubers. Control containers did not receive any treatments. Caraway seed and CIPC treatments were applied to each container once at the beginning of the experiment. After treatments were applied lids of containers closed tightly. In order to allow oxygen exchange for respiration of tubers lids were opened every two days for 10 minutes.

Tubers were stored for a total of 135 days starting from November 2008 to March 2009. Observations were taken at 15 day intervals throughout the experiment. Sprouting rate, length of sprouts, weight loss and number of sprouts on tubers were recorded. Sprouting considered to begin when sprouts were seen on tubers. Experiment was set up as Randomized Complete Block Design with 3 replications. Controls received no treatments, and CIPC treatment was also used as control. Analysis of variance (ANOVA) for treatments was performed using SAS statistical program (SAS Institute 1997). Effects of storage temperature and storage period were analyzed separately to find effects of each temperature and storage period on tubers.

RESULTS AND DISCUSSION

Sprouting Rate

Tuber sprouting was completely inhibited by CIPC and ground seed treatments until day 105 of storage when tubers were stored at 8 ^{o}C. At 120th day, sprouting was started and the lowest sprouting rates were recorded for G150 (13.3%) and CIPC (16.7%) treatments at the end of the storage period (Figure 1). Whole seed treatments did not prevent sprouting but delayed sprouting on stored tubers as compared to the control. Sprouting was complete on control tubers at the day 105 and at the same storage period whole seed treatments did not prevent sprouting but they had lower rates of sprouting compared to control (Figure 1).

For tubers stored at 15 ^{o}C, G50, G100 and G150 treatments completely inhibited sprouting at days 90, 75 and 105, respectively. At the end of the experiment, sprouting rates were close to each other for ground seed treatments but the best result was obtained from G50 treatment (30%), followed by G100 and G150 treatments (36.7%). Sprouting on tubers was observed at day 15 of the experiment for the CIPC treatment, and at the end of the experiment 43.3% sprouting was recorded for the CIPC treatment. In general, CIPC treatment was not as effective as ground seed treatments but it was more effective than whole seed treatments. Sprouting began at day 15 for whole seed treatments (Figure 2). At day 90, sprouting was complete on control whereas at day 90 sprouting was 50% on whole seed treatments, and at the end of the experiment 85% sprouting was recorded for whole seed treatments. Effects of S-(+)-Carvone to prevent sprouting of potato tubers were reported by other researchers (Hartmans et al., 1995; Oosterhaven et al., 1995). Our results showed delayed sprouting for whole seed treatments and complete inhibition of sprouting for a long time at 8 ^{o}C and 15 ^{o}C for ground seed treatments. Lower rates of sprouting observed in whole seed treatments may have been result from slow emission of S-(+)-Carvone into containers.

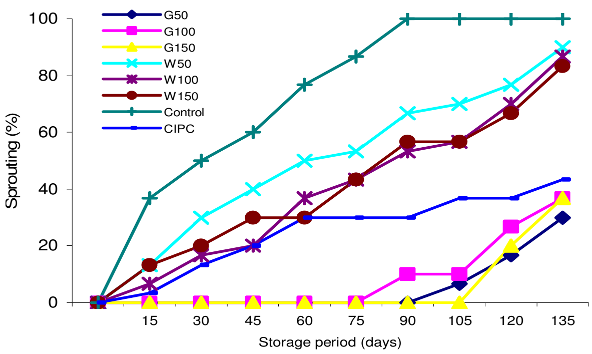

Figure 1. Sprouting rate of tubers at 8 °C (%)

Weight Loss

At the end of the experiment, 5.19% and 1.39% weight losses were recorded for control and CIPC treated tubers, respectively, and ground and whole seed treatments had 1.3% and 3.6% weight losses, under 8 ^{o}C storage conditions (Figure 3). Ground seed treatments showed similar results for weight loss. G100 and G150 treatments had 1.27% and G50 showed 1.51% weight loss. Sprouting started within the last month of the experiment for the CIPC and ground seed treatments and steady weight loss was recorded for all treatments during the experiment, but after sprouting, weight losses have become pronounced for the CIPC and ground seed treatments (Figure 3). The main reason for weight loss

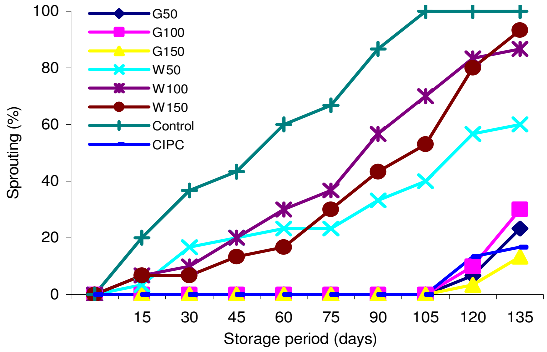

Figure 2. Sprouting rate of tubers at 15 °C (%)

during the storage is moisture loss, respiration and other metabolic processes of stored tubers, and increased weight loss of tubers with increased sprouting was reported (Burto, 1966; Wong Yen Cheong and Govinden, 1998; Yosuke et al., 2000; Suhag et al., 2006; Katundu et al., 2007).

The least weight loss was observed for ground seed treatments at 15 ^{o}C (Figure 4). The most effective treatment for preventing weight loss was G150 (2.28%), followed by G50 (2.46%) and G100 (2.74%) treatments. CIPC treatment was not as effective as ground seed treatments to prevent weight loss (3.02%). Control treatment exhibited the highest weight loss (7.05%). Weight losses of whole seed treatments during storage were ranged between 3.82-4.08%.

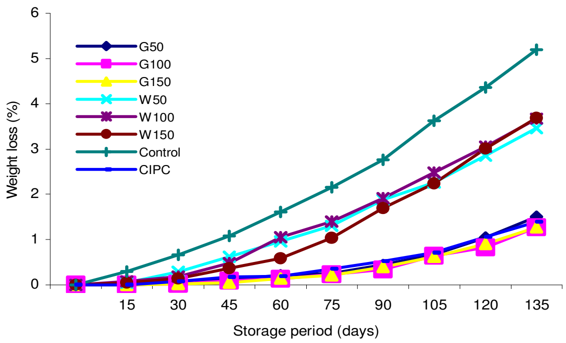

Figure 3. Weight loss of tubers stored at 8 °C (%)

Whole and ground seed treatments were more effective in controlling weight losses of tubers at 8 ^{o}C than they were at 15 ^{o}C. Breakdown of dormancy is influenced by many factors such as temperature. Increased temperatures during storage lead sprouting of tubers which leads to the loss of starch and eventual weight loss of tubers (Burton 1966; Song et al., 2004; Suhag et al., 2006; Costa et al., 2007).

Sprout Length

Sprouting started after 105 days for ground seed and CIPC treatments and consequently shortest sprout length was observed for these treatments at 8 ^{o}C. CIPC was the most effective treatment to reduce the growth of sprout length (1.7 mm) followed by G150 (3.3 mm) and G50 and G100 treatments (4.3 mm) (Figure 5). Control treatment had the longest sprout length at 8 ^{o}C at the end of the experiment (41.7 mm). Sprout lengths recorded for whole seed treatments were lower than the control treatments, but they had higher sprout lengths than CIPC and ground seed treatments. Sprout length started to be recorded at day 15 for W100, W150 and control treatments and at day 30 for W50 treatment and sprout length steadily increased during the experiment. At the end of the experiment, the shortest sprout length was found in W50 (18.0 mm) treatment among the whole seed treatments. W100 and W150 treatments had 25.3 mm and 26.7 mm sprout length, respectively (Figure 5).

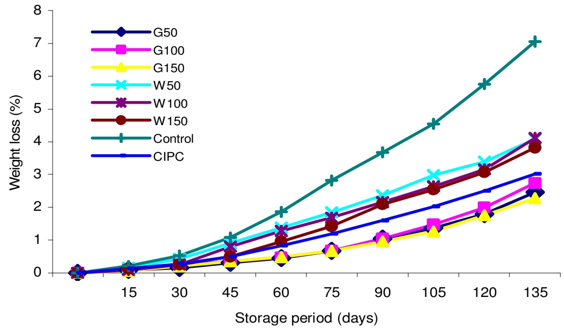

Figure 4. Weight loss of tubers stored at 15 °C (%)

Sprouting was inhibited until day 75, 90 and 105 for G100, G50 and G150 treatments, respectively at 15 ^{o}C. As a result, lengths of sprouts were limited by late sprouting observed in these treatments as compared to whole seed treatments (Figure 6). Sprouting was observed for all the remaining treatments at day 15. Once sprouting began, sprout lengths of tubers increased gradually for all treatments during the experiment. Although sprouting was not inhibited by the CIPC treatment at the beginning of the experiment at 15 ^{o}C, the shortest sprout length was recorded for CIPC treatment (6.0 mm) at the end of the storage period. Sprouting was delayed for ground seed treatments but after sprouting, these treatments gave higher sprout lengths than the CIPC treatment. The shortest sprout length was recorded for G150 (7.7 mm). G50 and G100 treatments had 8.0 mm and 9.3 mm sprout lengths at the end of the experiment. Sprout length increased in whole seed treatments with the increased dose and the longest sprout length was observed in W150 (42.0 mm) and in control treatment (57.3 mm) (Figure 6).

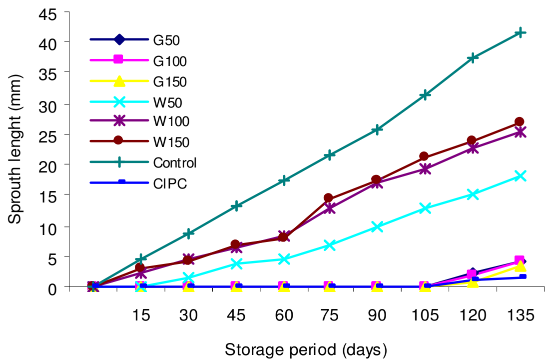

Figure 5. Sprout length of tubers stored at 8 °C (mm)

Potato tubers start sprouting when dormancy is broken and sprout lengths continue to increase as long as they could obtain nutrients from tubers. Effective organic compounds such as; S-Carvone, present in caraway seeds may have been lost in ground seed treatments as a result of aeration during the experiment or S-Carvone may have not been released effectively into containers from whole caraway seeds during the storage resulting in observed sprouting and sprout length in these treatments. Effective control of sprouting and sprout length was reported with application of commercial S-Carvone to potato tubers (Hartmans et al., 1995; Oosterhaven et al., 1995). In this experiment, statistically significant reductions in sprout length were achieved by the CIPC and ground seed treatments at 8 ^{o}C and 15 ^{o}C.

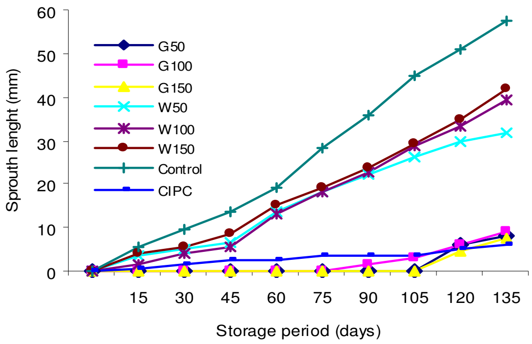

Figure 6. Sprout length of tubers stored at 15 °C (mm)

Number of Sprouts per Tuber

Sprout development was observed at the beginning of the experiment for control and whole seed treatments at 8 ^{o}C (Figure 7). Sprouting was observed at day 105 for CIPC and ground seed treatments. At the end of the experiment, control treatment had 6.7 sprouts per tuber at 8 ^{o}C. CIPC and ground seed treatments produced the lowest number of sprouts per tuber and at the end of the experiment all treatments had 0.8 sprouts per tuber (Figure 7). For the whole seed treatments, sprout number varied between 2.7-4.0 per tuber, and the lowest and the highest number of sprouts on tubers was found in W50 and W100 treatments, respectively.

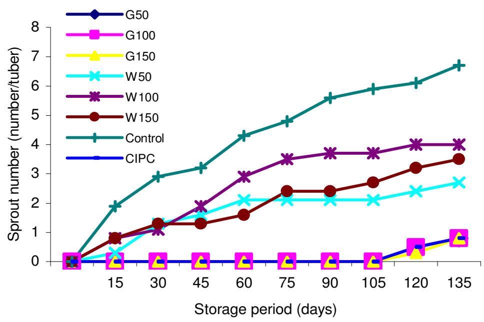

Figure 7. Number of sprouts on tubers at 8 °C (number/tuber)

Sprouting on tubers was delayed until day 90 for G50, day 75 for G100 and day 105 for G150 treatments at 15 ^{o}C. As a result, the lowest number of sprouts per tuber was recorded for the ground seed treatments (Figure 8). Sprouting was observed at day 15 for the rest of the treatments. Control treatment had the highest number of sprouts per tuber (9.1) and the lowest number of sprouts per tuber was observed in G150 (1.3), G50 (1.4) and G100 (1.7) treatments at day 135. Although sprouting on tubers was observed at the beginning of the experiment for the CIPC treatment, this treatment had only 1.9 sprouts per tuber (Figure 8). Number of sprouts for W150 treatment was 4.0 per tuber and for treatments W50 and W100 number of sprouts per tuber were 4.5. Respiration rate of tubers increases with increased storage temperatures and this situation leads sprouting and increases number of sprouts on tubers (Burton 1966; McGee et al., 1986).

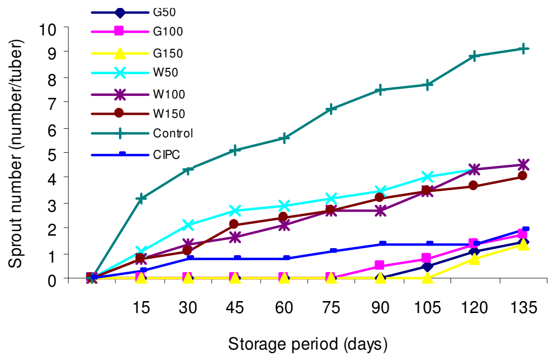

Figure 8. Number of sprouts on tubers at 15 °C (number/tuber)

In conclusion; sprouting was prevented by the CIPC and ground seed treatments at 8 ^{o}C until day 105 and at 15 ^{o}C, sprouting was prevented till day 75 by ground seed treatments. Minimum sprout length was observed in the CIPC and G150 treatments at 8 ^{o}C and 15 ^{o}C. The lowest number of sprouts per tuber was observed for the CIPC and ground seed treatments at 8 ^{o}C. Ground seed treatments gave shorter sprout lengths than the CIPC treatment at 15 ^{o}C. In general, the most effective treatments to reduce weight loss of tubers were the ground seed treatments at 8 ^{o}C and at 15 ^{o}C. Ground seed treatments significantly reduced rate of sprouting on tubers, sprout length, number of sprouts per tuber and weight loss of tubers at 8 ^{o}C and 15 ^{o}C. Ground caraway seeds could be used to extent storage period of tubers and alleviate the effects of high temperature storage on tubers.

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