Effect of Seed Priming on Germination, Field Emergence and Yield in Carrot (*Daucus carota* L.)

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ABSTRACT

A field experiment was carried out at Rampur, Chitwan in split-plot design to study the effect of priming of carrot seed on germination, early emergence, field emergence, plant stand establishment and root yield and quality. The treatments consisted of two commercial varieties of carrot (New Kuroda and Nantes Fancy) as main plot and seven levels of seed priming as sub-plots with 3 replications. The treatment imposed seeds for the field experiment were also used for laboratory test with four replications. New Kuroda exhibited higher vigor index (637.2), faster early emergence (8.33 days), highest field emergence (56.33%) and plant stand (66.67%), thickest cortex diameter (1.70 cm) and higher economic yield of 22.13 t ha^{-1} (50.65% more than control) in 24 hrs. seed soaking in tap water than in non-primed seeds where as Nantes Fancy showed faster early emergence (8.66 days), highest field emergence (55.33%), higher plant stand (69.33%) and higher yield of 17.69 t ha^{-1} (9.94% more than control) in 12 hrs. seed soaking in 40^{0}C warm water.

Key words*:* Carrot, priming, germination, emergence, vigor

INTRODUCTION

Carrot is becoming an important commercial crop of Nepalese farmers. It is grown all over the country from temperate region to the tropical. Due to its nutritive and economic value, it has been realized that the crop needs to be improved in order to exploit them to its maximum potentiality. The total cultivated area of carrot in Nepal is about 772.6 ha with 12.5 t ha^{-1} productivity (VDD, 2006). The commercialization of carrot is directly related with the poverty reduction program due to its higher per unit area production which is 12-15 tons ha^{-1} (Raut, 1996) as compared to cereal crops and fetches high value in the market.

Among other vegetable crops, the nature of carrot seed is such that it exhibits lower germination capacity of 65 % (SDQCSS, 1995) and takes long duration of at least three weeks to germinate under Nepalese field conditions. ICAR (2002) reported that carrot seed takes 10-20 days for germination in the field condition and suggests seed soaking for 12 to 24 hours before sowing for better germination. Some farmers are using over night seed soaking treatment in Nepal. But the effect of the duration of pre-sowing seed soaking on germination and plant stand establishment and their subsequent effect on the economic yield have not been documented well in Nepal.

Priming is a water-based treatment process that is performed on seeds to increase uniformity of germination and early emergence from the soil. Priming decreases the time span between the emergence of the first and the last seedlings (Hill, 2001). Austin et al., (1969) reported that carrot seed soaking in water at 20 ^{0}C for 24 hrs followed by drying at 20^{0}C resulted in quick germination and the seedlings emerged in the field 3-4 days earlier than untreated seeds.

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Similarly, Pantielev et al. (1976) studied the effect of water soaking with other treatments and found that the soaking in water increased carrot field germination by 13 percent and increased yield as well up to 60 percent.

Shishkina and Galeev (1974) stated that carrot seeds of cultivar Nantes were soaked in Boron (0.01%) solution for 24 hours, dried and sown. The treated seed germinated better in the field and gave a thicker stand of larger roots than the control with 23 percent more yield. The use of 0.25% phosphorus solution as priming treatment in mung-bean seed also increased the yield in Pakistan. Similarly, Hsu et al. (2003) reported that the warm water soaking for four hours at 40 ^{0}C improved the percentage and mean emergence time of bitter gourd at sub-tropical temperature of 20 ^{0}C.

By realizing beneficial effect of seed priming on carrot, the present study was planned to study the effect of various priming techniques including local methods which is known to some farmers of Nepal but not verified by scientific study under Nepalese condition. So, this study aims at assessing the effect of various methods of seed priming on carrot seed germination, field emergence, plant stand establishment and, ultimately, the yield and quality of carrot crop.

MATERIALS AND METHODS

The study encompassed two sets of works; field experiment to assess field emergence and yield and quality of carrot production and lab experiment to compare the germination percentage and seedling vigor of the treated and untreated seeds. The experiment was conducted at Horticulture Farm of the Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan. The lab work was done at the Horticulture lab of IAAS.

The treatments consisted of two commercial varieties of carrot viz. New Kuroda ($V1_{NK}$) and Nantes Fancy ($V2_{NF}$) as main plots and seven levels of seed priming as sub-plots with 3 replications. Seed priming treatments were: seed without soaking as control ($T1_C$), 12 hours seed soaking in tap water ($T2_{12TW}$), 12 hours seed soaking in 40 ^{0}C warm water (initially heated up to 40^{0}C) ($T3_{12WW}$), 24 hours seed soaking in tap water ($T4_{24TW}$), 24 hours seed soaking in 40 ^{0}C warm water ($T5_{24WW}$), 24 hours seed soaking in 0.01% (880 gm borax lt^{-1} of water) boron solution ($T6_{24TW+B}$) and 24 hours seed soaking in 0.25 % (16.5 gm single super phosphate lt^{-1} of water) phosphorus solution ($T7_{24TW+P}$) each followed by 2 hours shade drying.

The total experimental area was 18.1 m ×13.4 m. The main plot size was 11.4 m × 4.7 m with seven sub plots within each main plot. The sub plot size was 2.52 m^2. A total of 84 plants were accommodated in a sub-plot plot with 7 rows and 12 plants per row spaced at 30 cm row-to-row and 10 cm plant-to-plant. The area of net observable sub-plot was 1.5 m^2 with 50 plants.

Priming treatments consisted of soaking the seeds of both the varieties in tap water, warm water, and different micro and macronutrient solutions for 12 and 24 hours followed by 2 hours drying in shade. The warm water was monitored by initially heating up the water to 40^0 C, pouring seed and leaving it to cool down in the lab room for soaking periods as described in the treatments.

Land ploughing was done by tractor. Weeding, leveling and final land preparation was done manually. Basal application of manure and fertilizers was done at the rate of 20 mt farmyard manure and 30:40:40 NPK per hectare. At forty-five days after sowing, additional dose of nitrogen @ 30 kg ha^{-1} was top dressed. The seeds were obtained from agro-vet called Nemcol, Kalimati, Kathmandu. Both are popular varieties among the commercial farmers.

Seed sowing was done in the third week of November (Nov 23, 2005). It was done by counting the seeds per hill in all plots. Two seeds per hill at 1 cm depth were sown and there were 168 seeds sown in a sub plot. The spacing was 30×10 cm. Light irrigation was applied

after two days of seed sowing and the irrigation application was followed in every 15 days interval. First light hand weeding was done after two weeks of sowing. Hoeing, weeding and top dressing (ICAR, 2000) was done in forty-five days.

The treatment imposed seeds for the field experiment were also used for laboratory test with four replications. Hundred seeds of each treatment were placed in the petridish containing moist blotting paper with distilled water and the temperature of the germinator was maintained at 20^0C.

Observations recorded

Number of seedlings emerged were counted everyday just after the emergence. It was continued till there was 50 percent emergence in each sub-plot and number of days taken was recorded for early emergence. Total number of seedlings emerged were counted on 21^{th} day after sowing (DAS) in each sub-plot where hundred seeds were being sown @ 2 seeds per hill in 50 hills. Total number of plant stand was counted on 45^{th} DAS. Thinning was necessary to observe the total stand establishment of individual sub-plot so it was counted just after thinning.

The total economic yield of each sub-plot was calculated by subtracting the shoot and non-marketable yield of that particular sub-plot. Very small roots, forked roots, splitted roots and disease infected roots were accounted as non-marketable yield. The net area of each sub-plot harvested was $1.5m^2$. After measuring the root diameter at three places, it was cut transversely at those places. Core diameter was recorded and the mean calculated. Thus, average of 5 plants gave core diameter. Likewise, cortex diameter was computed by using the following formula:

Cortex diameter (cm) = Root diameter - Core diameter.

On fourteenth day of the placement of seeds in the germinator number of normal seedlings was counted and the seedling length (root + shoot length) of ten randomly selected normal seedlings under each treatment were recorded and average value was calculated. The vigor index was computed by using the following formula (Abdul-Baki and Anderson, 1973):

Vigor index = % Germination × seedling length (shoot length + root length).

Statistical analysis

MSTAT (1990) statistical computer software was used for ANOVA analysis and Microsoft Excel (2000) was used for drawing graphs. The treatment means were compared by DMRT at P = 0.05.

RESULTS AND DISCUSSION

Days to 50% early emergence

The effect of carrot seed priming and variety on days to 50% early emergence is presented in Table 1. Except seed priming treatments, the varieties did not differ in respect of days to 50% early emergence. $T3_{12WW}$ took least number of days (9.66) to 50% early emergence than the control $T1_C$ (12.33 days), the difference being significant.

Table 1. Effect of variety and seed priming on days to 50% early emergence in carrot crop at IAAS, Rampur. Chitwan,, 2005/06.

	Days to 50% early emergence		
Priming	$V1_{NK}$	$V2_{NF}$	Priming Mean (P)
$T1_C$	13.67^a	11.00^{cde}	12.33^a

$T2_{12TW}$	11.33^{bcde}	9.00^{fgh}	10.17^{c}
$T3_{12WW}$	10.67^{cdef}	8.66^{gh}	9.66^{c}
$T4_{24TW}$	8.33^{h}	12.00^{abcd}	10.1^{c}
$T5_{24WW}$	8.667^{gh}	12.33^{abc}	10.50^{bc}
$T6_{24TW+B}$	10.33^{defg}	13.00^{ab}	11.67^{ab}
$T7_{24TW+P}$	10.67^{cdef}	10.00^{efgh}	10.33^{c}
Variety Mean (V)	10.52^{a}	10.86^{a}	
LSD (5%) for variety V		ns	
SE		0.2630	
LSD (5%) for priming P		1.203	
SE		0.4123	
LSD (5%) for V × P		1.702	
SE		0.5831	
CV%		9.45	

Figures followed by the same letter (s) are not significantly different at P = 0.05 by DMRT.
ns = non significant (P>0.05).

The interaction between variety and seed priming on days to 50% early emergence was significant. Within variety $V1_{NK}$, $T4_{24TW}$ (24 hrs. seed soaking in tap water) resulted into the lowest number of days (8.33) to 50% early emergence, which was 5.34 days earlier than the control $T1_{C}$ (13.67 days).

Similarly, within variety $V2_{NF}$, $T3_{12WW}$ (12 hrs. seed soaking in 40 ^{0}C warm water) took lowest number of days (8.66) to 50% early emergence which was 2.34 days earlier than the control $T1_{C}$ (11.00 days). The difference was significant. The present finding on early emergence agrees with Wilkinson (1918) who reported about the placement of seeds of radish, bean, corn, cucumber and squash in luke-warm water overnight to increase the germination velocity.

The interactive result of variety and seed priming agrees with the findings of Austin et al., 1969 who also reported that soaking carrot seeds at 20 ^{0}C for 24 hr resulted into quick germination and the seedlings emerged in the field 3-4 days earlier than untreated seeds. The findings of this study also agree with Nagarajan et al., 2005 who reported that seed priming reduced the number of strong binding sites and the associated water content, and increased significantly the number of weak binding sites and the associated water content. This redistribution of water which increased the availability of seed water may be the reason for the higher speed of germination of primed seeds.

The early emergence of primed seed in the field might be due to the completion of I and II stages of germination process during the priming period. Gray et al., 1990 suggested that during priming the seeds are artificially maintained in phase II of imbibition and the substances generated in this latent period may increase cell wall or remove restrictions for radicle growth.

Effect on total field emergence (%)

The effect of seed priming on total field emergence was not significant (Table 2). Likewise, varieties also did not differ. But the variety $V1_{NK}$ showed the higher percentage of plant emergence (48.67%) compared to $V2_{NF}$ (43.05%). Although not significant, $T3_{12WW}$ exhibited the highest percentage of field emergence (51.17%) followed by $T4_{24TW}$ (48.50%) where as control exhibited (44.83%) only.

In variety $V1_{NK}$, $T4_{24TW}$ exhibited significantly the highest (56.33%) total field emergence of seedling compared to the control $T1_C$ (41.33%). Similarly, within variety $V2_{NF}$, $T3_{12WW}$ has resulted the highest (55.33%) field emergence than the control $T1_C$ (48.33%) both being at par with each other.

Table 2. Effect of variety and seed priming on total field emergence in 21 DAS (%) in carrot crop at IAAS, Rampur. Chitwan,, 2005/06.

	Total field emergence (%)		
Priming	$V1_{NK}$	$V2_{NF}$	Priming Mean (P)
$T1_C$	41.33^{bcd}	48.33^{abcd}	44.83^{a}
$T2_{12TW}$	48.33^{abcd}	41.00^{bcd}	44.67^{a}
$T3_{12WW}$	47.00^{abcd}	55.33^{ab}	51.17^{a}
$T4_{24TW}$	56.33^{a}	40.67^{bcd}	48.5^{a}
$T5_{24WW}$	53.33^{abc}	36.33^{d}	44.5^{a}
$T6_{24TW+B}$	46.33^{abcd}	38.67^{cd}	42.50^{a}
$T7_{24TW+P}$	48.00^{abcd}	41.00^{bcd}	44.50^{a}
Variety Mean (V)	48.67^{a}	43.05^{a}	
LSD (5%) for variety V		Ns	
SE		2.416	
LSD (5%) for priming P		Ns	
SE		3.101	
LSD (5%) for V × P		12.80	
SE		4.386	
CV%		16.56	

Figures followed by the same letter (s) are not significantly different at P = 0.05 by DMRT.
ns = non significant (P>0.05). DAS = Days After Sowing

The improvement in total percentage emergence and mean emergence time of bitter gourd soaked in hot water as reported by Hsu et al. (2003) agrees with the highest total field emergence and stand establishment found in $T3_{12WW}$ in this study.

The interactive effect of priming and variety on field emergence in this study agrees with the findings of Pantielev et al., 1976 who reported that the carrot seed soaking in water increased field germination by 13 %. In this study variety $V1_{NK}$ (New Kuroda) showed about 36% more seedling field emergence at $T4_{24TW}$ than control $T1_C$.

The result exhibited that the variety $V1_{NK}$ preferred 24 hrs seed soaking in tap water while $V2_{NF}$ (Nantes Fancy) preferred the 12 hrs seed soaking in warm water for better field emergence. Carrot seed has low permeable seed coat which delayed the imbibed period and other metabolic activities within the seed. Visual observation shows that the seeds of Nantes have thin pellets than the New Kuroda. So, from this study it can be concluded that the thin pellets of Nantes seed might be the reason for less time needed to imbibe and gain priming benefit.

Effect on total plant stand establishment (%)

The varieties did not differ in respect of total plant stand establishment (Table 3). But the variety $V1_{NK}$ demonstrated the higher percentage of plant stand establishment (57.05%) out of fifty plants after thinning as compared to the variety $V2_{NF}$ (53.43%). Priming treatment $T3_{12WW}$ showed the highest percentage of plant stand (63.33%) as compared to the control $T1_C$ (51.67%).

Table 3. Effect of variety and seed priming on total plant stand establishment (%) in carrot crop at IAAS, Rampur. Chitwan, 2005/06.

	Total plant stand establishment (%)		
Priming	$V1_{NK}$	$V2_{NF}$	Priming Mean (P)
$T1_{C}$	44.67^{cd}	58.67^{abcd}	51.67^{a}
$T2_{12TW}$	58.00^{abcd}	48.00^{bcd}	53.00^{a}
$T3_{12WW}$	57.33^{abcd}	69.33^{a}	63.33^{a}
$T4_{24TW}$	66.67^{ab}	46.67^{bcd}	56.67^{a}
$T5_{24WW}$	64.67^{abc}	43.33^{d}	54.00^{a}
$T6_{24TW+B}$	55.33^{abcd}	50.67^{abcd}	53.00^{a}
$T7_{24TW+P}$	52.67^{abcd}	57.33^{abcd}	55.00^{a}
Variety Mean (V)	57.05^{a}	53.43^{a}	
LSD (5%) for variety V		ns	
SE		2.935	
LSD (5%) for priming P		ns	
SE		4.362	
LSD (5%) for V × P		18.01	
SE		6.169	
CV%		19.34	

Figures followed by the same letter (s) are not significantly different at P = 0.05 by DMRT.
ns = non significant (P>0.05).

The interaction of variety and priming on plant stand was significant. Within variety $V1_{NK}$, $T4_{24TW}$ showed highest (66.67%) total plant stand establishment than control $T1_{C}$ (44.67%). In case of $V2_{NF}$, $T3_{12WW}$ demonstrated the highest percentage (69.33%) of total plant stand establishment than control $T1_{C}$ (58.67%).

In this study, total plant stand was recorded about 49% more in treatment $T4_{24TW}$ (66.67%) than control $T1_{C}$ (44.67%) in variety $V1_{NK}$ (New Kuroda) while it was 18% more in treatment $T3_{12WW}$ (69.33%) in variety $V2_{NK}$ (Nantes Fancy) than control $T1_{C}$ (58.67%). The finding of this study agrees with the report of Hill (2001), who has reported that the priming increased the rate of emergence so the stand establishes itself faster.

The germination capacity and energy of the primed seed enhance the seedlings growth uniformly so that the growth of a plant is not affected by the shading effect of its neighboring plant. It shows that the priming treatment increases the probability of plant stand as compared to non primed one.

Effect on economic yield

Table 4 showed that varieties did not differ in respect of economic yield and so was the case among the priming treatments. Comparatively, $V1_{NK}$ yielded higher (16.92 tha^{-1}) than $V2_{NF}$ (15.41 t ha^{-1}). Among priming treatments, $T4_{24TW}$ gave the highest yield (18.22 t ha^{-1}) followed by $T3_{12WW}$ (17.42 t ha^{-1}). The lowest yield was produced by the treatment $T7_{24TW+P}$ (14.69 t ha^{-1}) followed by $T5_{24WW}$ (14.79 t ha^{-1}).

Table 4. Effect of variety and seed priming on economic yield (t ha^{-1}) in carrot crop at IAAS, Rampur. Chitwan,, 2005/06.

	Economic yield (t ha^{-1})		
Priming	$V1_{NK}$	$V2_{NF}$	Priming Mean (P)
$T1_{C}$	14.69^{b}	16.09^{ab}	15.39^{a}
$T2_{12TW}$	16.29^{ab}	15.96^{ab}	16.12^{a}
$T3_{12WW}$	17.16^{ab}	17.69^{ab}	17.42^{a}
$T4_{24TW}$	22.13^{a}	14.31^{b}	18.22^{a}
$T5_{24WW}$	16.76^{ab}	12.82^{b}	14.79^{a}
$T6_{24TW+B}$	17.31^{ab}	15.69^{b}	16.50^{a}
$T7_{24TW+P}$	14.09^{b}	15.29^{b}	14.69^{a}
Variety Mean (V)	16.92^{a}	15.41^{a}	
LSD (5%) for variety V		Ns	
SE		1.062	
LSD (5%) for priming P		Ns	
SE		1.346	
LSD (5%) for V × P		5.555	
SE		1.903	
CV%		20.40	

Figures followed by the same letter (s) are not significantly different at P = 0.05 by DMRT.

ns = non significant (P>0.05).

The interaction of variety and priming treatments on economic yield showed that in V_{NK}, treatment $T4_{24TW}$ gave highest economic yield (22.13 t ha^{-1}) as compared to the control $T1_{C}$ (14.69 t ha^{-1}) and $T7_{24TW+P}$ (14.09 t ha^{-1}). In variety $V2_{NF}$, the highest economic yield was recorded from $T3_{12WW}$ (17.69 t ha^{-1}) as compared to the control $T1_{C}$ (16.09 t ha^{-1}). The lowest yield was recorded from $T5_{24WW}$ (12.82 t ha^{-1}).

The finding of this study on economic yield as affected by priming treatments showed 18.39 % more root yield due to $T4_{24TW}$ (24 hr seed soaking in tap water) over the control $T1_{C}$. Similarly, the interaction of variety and seed priming on economic yield showed that, in variety $V1_{NK}$ (New Kuroda), treatment $T4_{24TW}$ gave 50.65 % more yield than the control while in variety $V2_{NF}$ (Nantes Fancy) 9.94 % more yield was recorded by the treatment $T3_{12WW}$ (12 hrs seed soaking in warm water) than control but it has recorded 37.98% more yield than the treatment $T5_{24WW}$.

The present finding of variety $V1_{NK}$ and priming effect agrees with the report of Pantielev et al. (1976) who reported that the carrot seed soaking in water increased yield up to 60%. However, the result was not encouraging in case of variety $V2_{NF.}$ The result of variety $V2_{NF}$ was similar to findings by Austin et al., 1969, who reported the yield of carrot roots from the hardened seeds was 64 t ha^{-1} compared to 59.2 t ha^{-1} from untreated seeds.

The treatment $T4_{24TW}$ i.e. seed soaking in tap water for 24 hrs in the variety $V1_{NK}$ (New Kuroda) showed consistence level of the highest record in most of the parameters except the important parameter root length but the difference was not big. Early emergence, total field emergence, total plant stand establishment and number of leaves per plant with plant height to yield parameters were leading with this treatment. Similar trend can be observed in the variety $V2_{NF}$ (Nantes Fancy) with the treatment $T3_{12WW}$ i.e. 12 hrs seed soaking in warm water. So,

traditional practice of one night seed soaking by farmers and favorable results due to 24 hrs seed soaking as reported by different scientists seem true but it varies with the cultivars.

Effect on cortex diameter

Cortex diameter in $V1_{NK}$ (1.60 cm) was comparatively bigger than that in $V2_{NF,}$ (1.35 cm), the difference being non significant (Table 5). However, priming effect on cortex diameter was significant. Treatment $T4_{24TW}$ produced the highest cortex diameter (1.56 cm) as compared to the control $T1_C$ (1.29 cm). All the priming treatments were at par with$T4_{24TW}$. All priming treatments except phosphorus solution ($T7_{24TW+P}$) showed significantly bigger cortex diameter than control.

In interaction of variety and priming on cortex diameter, $T4_{24TW}$ produced the highest cortex diameter (1.703 cm) as compared to the control (1.360 cm) in variety $V1_{NK}$. In variety $V2_{NF}$, $T6_{24TW+B}$ produced the highest (1.450) cortex diameter as compared to the control $T1_C$. The difference was not significant. All other treatments were at par with the treatment $T6_{24TW+B.}$

Effect on vigor

Varieties did not differ with respect to vigor index (Table 6). Variety $V1_{NK}$ showed the highest vigor index (525.9) as compared to variety $V2_{NF}$ (493.1). The priming effect on vigor index was significant. Treatment $T4_{24TW}$ resulted into significantly the highest index of 564.2 as compared to the lowest record of treatment $T6_{24TW+B}$ (389.0).

The interaction showed that vigor index was the highest (637.2) in $T4_{24TW}$ in variety $V1_{NK}$. Treatment $T4_{24TW}$ was found significantly higher (637.2) than the treatment $T6_{24TW+B}$ with index 278.6 which was lower than control $T1_C$ (452.3). All other treatments were at par with the treatment $T4_{24TW}$. In variety $V2_{NF}$, $T7_{24TW+P}$ resulted into the highest index of 527.7 followed by $T3_{12WW}$ (511.8). Both gave higher value as compared to control $T1_C$ (452.3) but they were not significantly different.

Table 5. Effect of variety and seed priming on cortex diameter (cm) in carrot crop at IAAS, Rampur. Chitwan,, 2005/06.

	Cortex diameter (cm)		
Priming	$V1_{NK}$	$V2_{NF}$	Priming Mean (P)
$T1_{C}$	1.360^{cde}	1.230^{e}	1.295^{b}
$T2_{12TW}$	1.633^{ab}	1.403^{bcde}	1.518^{a}
$T3_{12WW}$	1.690^{a}	1.277^{e}	1.483^{a}
$T4_{24TW}$	1.703^{a}	1.420^{bcde}	1.562^{a}
$T5_{24WW}$	1.617^{abc}	1.390^{bcde}	1.503^{a}
$T6_{24TW+B}$	1.643^{ab}	1.450^{abcde}	1.547^{a}
$T7_{24TW+P}$	1.567^{abcd}	1.333^{de}	1.450^{ab}
Variety Mean (V)	1.602^{a}	1.358^{a}	
LSD (5%) for variety V		ns	
SE		0.05255	
LSD (5%) for priming P		0.1642	
SE		0.05627	
LSD (5%) for V × P		0.2323	
SE		0.07958	
CV%		9.36	

Figures followed by the same letter (s) are not significantly different at P = 0.05 by DMRT.

ns = non significant (P>0.05).

Table 6. Effect of variety and seed priming on vigor index in carrot seed at IAAS laboratory, Rampur. Chitwan,, 2005/06.

	Vigor index		
Priming	$V1_{NK}$	$V2_{NF}$	Priming Mean (P)
$T1_{C}$	554.3^{ab}	452.3^{b}	503.3^{a}
$T2_{12TW}$	518.2^{ab}	464.1^{b}	491.2^{a}
$T3_{12WW}$	587.9^{ab}	511.8^{ab}	549.8^{a}
$T4_{24TW}$	637.2^{a}	491.1^{ab}	564.2^{a}
$T5_{24WW}$	573.5^{ab}	505.2^{ab}	539.3^{a}
$T6_{24TW+B}$	278.6^{c}	499.3^{ab}	389.0^{b}
$T7_{24TW+P}$	531.7^{ab}	527.7^{ab}	529.7^{a}
Variety Mean (V)	525.9^{a}	493.1^{a}	
LSD (5%) for variety V		ns	
SE		10.72	
LSD (5%) for priming P		102.1	
SE		35.59	
LSD (5%) for V × P		96.49	
SE		33.64	
CV%		19.76	

Figures followed by the same letter (s) are not significantly different at P = 0.05 by DMRT.
ns = non significant (P>0.05).

Seed vigor has been used to distinguish seeds having the potential to produce strong, healthy seedlings and those with weakened performance potential. In the lab test the treatment $T4_{24TW}$ had highest vigor index (637.2) in variety $V1_{NK}$ where as in variety $V2_{NF}$, $T7_{24TW+P}$ had the highest (527.7) index which was followed by $T3_{12WW}$ (511.8). This result of lab test was directly related with the result of field seedling emergence with respect to early and total field emergence. The days to 50% early emergence and total field emergence in both the varieties New Kuroda and Nantes Fancy were lead by the treatments $T4_{24TW}$ and $T3_{12WW}$.

From the laboratory study it can be concluded that the major benefits of priming were faster germination and higher germination percentage which encourage for further test in other vegetables too.

CONCLUSION

This study focused on simple and low cost technology to find out the effect of duration of water soaking on various parameters from carrot seed emergence to root yield. Water soaking for duration of 12 to 24 hrs has been found appropriate for two commercial varieties of carrot seed. The popular commercial variety New Kuroda ($V1_{NK}$) exhibited highest vigor index (637.2), faster early emergence (8.33 days), highest field emergence (56.33%) and plant stand (66.67%), thickest cortex diameter (1.70 cm) with highest economic yield of 22.13 t ha^{-1} (50.65% more than control) in 24 hrs seed soaking in tap water than non primed seeds where as another commercial variety Nantes Fancy ($V2_{NF}$) showed faster emergence (8.66 days), highest field emergence (55.33%), higher plant stand (69.33%) and more economic yield (9.94% more than control) in 12 hrs seed soaking in 40^0C warm water.

From the study, it can be suggested to choose 24 hrs seed soaking in tap water for better yield of New Kuroda and 12 hrs seed soaking in 40^0C warm water for better yield with less green shouldered roots of Nantes Fancy. For confirmation, one more verification trial may be suggested.

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