# EFFECTIVE HARDENING OF PAPRIKA (CAPSICUM ANNUUM L) SEEDLINGS FOR GOOD FIELD ESTABLISHMENT AND FRUIT YIELD IN THE SMALLHOLDER SYSTEM

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# Abstract

On-farm trials were conducted in the Chinyika Resettlement Area of Zimbabwe during the 2000-2002 cropping seasons to assess the effectiveness of hardening methods for seedlings of two paprika cultivars ('PapriKing' and 'Red Tsar') in the smallholder system. The hardening treatments compared include: H0 – regularly watering seedlings up to transplanting; H1 – seedling watering stopped two weeks transplanting; H2 – water withheld at the beginning of 5th week by skipping one day during the 5th week, 2 days during the 6th week and then completely withhold watering beginning of the 7th week; H4 – no watering in the 6th and 7th weeks only; H5 – withholding water from 5th week until transplanting. Main effects of both cultivar and hardening methods were not significant but there were significant interactions between paprika cultivar and hardening method with respect to field establishment. When paprika seedlings were not hardened cv. 'Red Tsar' had a higher mortality but a higher fruit yield than cv. 'PapriKing'. Similarly, cultivars x hardening method interactions were significant for both total and marketable fruit yields. Unhardened cv. 'PapriKing' seedlings field established better than 'Red Tsar' seedlings. When the farmer does not have the opportunity or time to harden his paprika seedlings prior to transplanting, then his choice of variety becomes rather crucial. In other words, field establishment and paprika fruit yield were not determined by the main effects of either variety or method of seedling hardening, rather by their interaction. Effective hardening of seedlings occurred when water was withheld during two weeks preceding seedling seedling transplanting.

Key words: Capsicum annuum L cultivars, moisture stress, on-farm, seedling transplanting, transplant mortality

# **INTRODUCTION**

Paprika (*Capsicum annuum* L.) is an important commodity of major economic significance globally, with Hungary and Spain being the greatest producers in Europe. However, in the Southern Africa sub-region, Zimbabwe and South Africa are clearly the leading producers of this commodity. Unfortunately, production of the important cash crop under the smallholder production system is faced with a number of production problems and producers are therefore not able to take full advantage of the market demand.

Successful production of paprika is contingent upon a good field establishment of the crop after transplanting under the dryland system; being one of the production constraints identified in the smallholder sector (Chivinge and Mariga, 1998). Poor paprika transplant establishment in the field can result in high transplant mortality, sub-optimal plant population and serious weed challenge, even to extent of wiping out a crop. Poor field establishment of transplanted seedlings can be caused by various factors, part of which may be due to inadequate or lack of hardening of transplants.

Hardening is the process by which seedlings are transiently subjected to some harsh environmental conditions so as to enable them withstand stress or shock upon transplanting onto the field. This practice of preconditioning is normally meant for seedlings raised in sheltered seedbeds, where they would the exposed to direct sunlight and/or reduced water supply. The standard practice adopted for paprika seedlings is to withdraw water supply during a particular short phase of their growth in the seedbeds. In tobacco, for which this normally practiced, there is evidence that increased seedling hardiness leads to increased growth of transplants. This was attributed to a higher starch content of the plant cells, which results in faster growth of transplants (Ken Flower, personal communication).

Garmany and Bates (1957) pointed out that cutting water off too early leads to the production of too tough tobacco seedlings, which are slow to start growing again. If water is reduced when seedlings are halfgrown, their growth rate is slowed down and root development within the top 5 cm of the soil is hindered. Pre-transplanting nutritional conditioning is another procedure that has been successfully used to harden bell pepper seedlings (Dufault and Schultheis, 1994). This entails the withholding of nutrients such as nitrogen and phosphorus from seedlings thereby slowing down their growth up to transplanting time.

The recommended practice is to continuously harden seedlings by withholding water in the last two weeks (7<sup>th</sup> and 8<sup>th</sup> weeks) prior to transplanting. It was gathered through informal surveys that most farmers do not adhere to this hardening regime, but instead subject their seedlings to alternate watering and hardening. Research on how seedlings of different paprika cultivars are likely to respond to alternate watering and hardening

treatment has not been done in Zimbabwe. The objective of this study, therefore, was to assess the effectiveness of various methods of seedling hardening in two paprika cultivars based on their field establishment and fruit yield.

### MATERIALS AND METHODS

During the 2000/01 season, a field trial was conducted at the University of Zimbabwe Farm in Harare (lat. 17° 50' S; long. 31° 03'E; 1500 m above sea level), Zimbabwe. Prior to field establishment, paprika seedlings were raised in flat trays in a greenhouse, with sowing done on 7 November 2000. Compound "S" fertilizer (7 N : 27  $P_2O_5$  : 7  $K_2O$ ) was applied to the trays at a rate of 1 kg/10 m<sup>2</sup>. Two paprika cultivars, namely, 'PapriKing' and 'Red Tsar' were used. The six hardening methods that were compared are as follows: H0 - seedlings well watered until the day of transplanting; H1 - watering of seedlings was stopped two weeks prior to transplanting. They were only given survival irrigation when they wilted severely; H2 water gradually withheld at the beginning of the 5th week by skipping one day during the 5<sup>th</sup> week, skipping 2 days during the  $6^{th}$  week and then completely withhold watering beginning of the 7<sup>th</sup> week. Watering was only done when plants showed signs of wilting by 10:00 H; H3 – no watering in the  $5^{th}$  and  $7^{th}$  weeks and watering resumed in the 8<sup>th</sup> week until transplanting; H4 - no watering in the 6<sup>th</sup> and 7<sup>th</sup> weeks only; and H5 water withheld from the fifth week until transplanting and only applied when seedlings showed signs of wilting by 10:00 H.

Where transplanting could not be done exactly at the end of the 8<sup>th</sup> week after sowing, the treatment administered to the seedlings during the 8<sup>th</sup> week was continued until transplanting could be eventually done. After field preparation, transplanting of seedlings onto the field was done on 22 January 2001, i.e. 10 weeks after sowing (WAS). Treatments were factorial combinations of two paprika cultivars and six hardening methods laid out in randomised complete block design with three replications. Transplanting was done when the soil was moist, on ridges that were 0.9 m apart and intra-row spacing was 20 cm. A top dressing of potassium chloride (60% K<sub>2</sub>O) at a rate of 350 kg/ha was applied at 31 days after transplanting (DAT) but no ammonium nitrate was applied because it was not available. The trial was sprayed with a mixture of 30 g copper oxychloride (a.i copper oxychloride, 850 g/kg) and 30 g Dithane H45 (85%WP) a.i. mancozeb (800 g/kg) per 15 litres of water at 30 and 64 DAT to control bacterial leaf spot (Xanthomonas campestris pv vesicatoria). The trial was hoe-weeded twice, at 17 and 33 DAT. Plant establishment was assessed 4 WAT by counting the number of plants per net plot. Average fruit length was determined by sampling five representative fruits per plot.

In the 2001/02 season the trial was conducted at Mukada farm in Chinyika West. Sowing was done on 17 September 2001 and transplanting was done on 6 December 2001 (11 WAS). Weeding was done twice

Figure 1: Monthly rainfall for the period October to April 2000/01 and 2001/02 at Mukada in the Chinyika Resettlement Area, Zimbabwe



at 21 and 38 DAT. Ammonium nitrate and potassium chloride were applied 42 DAT each at a rate of 350 kg per hectare. Harvesting was done once on 31 March 2002 for the University of Zimbabwe experiment and twice, at 150 and 197 DAT, for the Mukada trial. During the first harvest only red and dried fruits were picked. During the second and final harvest all fruit categories (red and dry, red and succulent and green and unripe) were picked. Harvested paprika fruits were processed by allowing them to air-dry and then graded and classified into categories of marketable and nonmarketable fruits before weighing. Rainfall data for Chinyudze for the two seasons are presented in Figure 1.

Data collected were subjected to statistical analysis of variance to test for the significance of treatment effects (Snedecor and Cochran, 1980). In cases where these were significant, treatment means were partitioned using the Duncan's multiple range tests (Steel et al.; 1997).

# RESULTS

#### **Field establishment**

Hardening method and paprika cultivar main effects did not influence field establishment in both seasons (2000/01 and 2001/02) at Harare and Mukada (Tables 1 and 2). It was at Mukada farm that the various hardening methods produced slightly better field establishment than the no-hardening check. Whereas at Harare, the current recommended hardening method (i.e. stopping seedling watering two weeks prior to transplanting), gave the best field establishment.

However, there were significant cultivar x hardening method interactions for field establishment in 2001/02 at Mukada farm (Figure 2). Cultivar 'Red Tsar' seedlings were far more susceptible to non-hardening than 'PapriKing' seedlings with respect to field establishment of paprika, which was only slightly above 20 000 plants per hectare (2 plants/m<sup>2</sup>). Cultivar 'PapriKing', on the other hand, was able to maintain a good field establishment even in the absence of seedling hardening. While not watering of seedlings in the 5<sup>th</sup> and 7<sup>th</sup> weeks was somewhat detrimental to field establishment in 'PapriKing', that hardening method was actually of beneficial to 'Red Tsar' seedlings. The other hardening methods seemed to have performed

similarly for both cultivars with respect to their effect on field establishment. Cultivar 'Red Tsar' seedlings benefited by various hardening methods than did cultivar 'PapriKing'.

Hardening treatment conferred only limited advantage to the field establishment of 'PapriKing' transplants. Whereas, hardening had significant positive impact on the field establishment of 'Red Tsar' seedlings, which had equal or better field establishment than 'PapriKing' under H2, H4 and H5 hardening methods (Figure 2).

**Tab. 1:** Main effects of hardening method and cultivar on paprika fruit yield and field establishment at Harare, Zimbabwe in 2000/01 season

Treatment	Total fruit yield (kg/ha)	Marketable fruit yield (kg/ha)	Field establishment (plants/m <sup>2</sup> )
Hardening method			
$H0^{\#}$	1 561	1 058	3.3
H1	1 668	1 099	3.9
H2	1 460	970	3.5
Н3	1 460	949	3.3
H4	1 383	878	3.3
Н5	1 507	938	3.4
Significance	ns	ns	ns
Cultivar			
PapriKing	1 477	920	3.3
Red Tsar	1 536	1 043	3.5
Significance	ns	ns	ns
Mean	1 506.5	981.5	3.40

ns = difference between means not significant at p < 0.05

<sup>#</sup>H0 = Seedlings well watered until the day of transplanting; H1 = watering of seedlings was stopped two weeks prior to transplanting. They were only given survival irrigation when they wilted severely; H2 = water gradually withheld at the beginning of the 5<sup>th</sup> week by skipping one day during the 5<sup>th</sup> week, skipping 2 days during the 6<sup>th</sup> week and then completely withhold watering beginning of the 7<sup>th</sup> week. Watering was only done when plants showed signs of wilting by 10:00 H; H3 = no watering in the 5<sup>th</sup> and 7<sup>th</sup> weeks and watering resumed in the 8<sup>th</sup> week until transplanting; H4 = no watering in the 6<sup>th</sup> and 7<sup>th</sup> weeks only; and H5 = withhold water from the fifth week until transplanting and only applied when seedlings showed signs of wilting by 10:00 H.

Treatment	Total fruit yield (kg/ha)	Marketable fruit yield (kg/ha)	Field establishment (plants/m <sup>2</sup> )
Hardening method			
H0 <sup>#</sup>	420	277	2.5
H1	489	267	3.5
H2	559	307	3.4
Н3	485	371	3.3
H4	636	390	3.7
Н5	671	367	3.7
Significance	ns	ns	ns
Cultivar			
PapriKing	553	331	3.4
Red Tsar	534	329	3.3
Significance	ns	ns	ns
Mean	543.5	330.0	3.35

**Tab. 2:** Main effects of hardening method and cultivar on paprika fruit yield and field establishment at Mukada, Zimbabwe in 2001/02 season

Explanation see Table 1

Figure 2: Interaction between hardening method and cultivar on paprika field establishment at Mukada, Zimbabwe in 2001/02 season



H0 = Seedlings well watered until the day of transplanting; H1 = watering of seedlings was stopped two weeks prior to transplanting. They were only given survival irrigation when they wilted severely; H2 = water gradually withheld at the beginning of the 5<sup>th</sup> week by skipping one day during the 5<sup>th</sup> week, skipping 2 days during the 6<sup>th</sup> week and then completely withhold watering beginning of the 7<sup>th</sup> week. Watering was only done when plants showed signs of wilting by 10:00 H; H3 = no watering in the 5<sup>th</sup> and 7<sup>th</sup> weeks and watering resumed in the 8<sup>th</sup> week until transplanting; H4 = no watering in the 6<sup>th</sup> and 7<sup>th</sup> weeks only; and H5 = withhold water from the fifth week until transplanting and only applied when seedlings showed signs of wilting by 10:00 H.

Hardening produced as much as 108–125% field establishment advantage on 'Red Tsar' seedlings.

### Yield and yield-related parameters

Although there were no significant differences in fruit yield due to hardening method and cultivar main effects (Tables 1 and 2), however, there were significant (p < 0.05) interactions between hardening method and cultivar for both total and marketable fruit yields at Harare in 2000/01 season (Figures 3 and 4). The total and marketable fruit yields that came from seedlings that were hardened using the current recommended practice were only slightly better than the other hardening methods. They were quite similar to those of the non-hardened check. In terms of total fruit yield,

hardening had rather negligible effect on 'Red Tsar' seedlings; while total fruit yield in 'PapriKing' was enhanced by hardening using methods H1, H4 and H5 in particular (Figure 3). As much as 66–100% increase in total fruit yield was derived by hardening 'PapriKing' seedlings.

Hardening gave no advantage for marketable fruit yield in 'Red Tsar seedlings. However, hardened 'PapriKing' seedlings produced higher marketable fruit yield than non-hardened ones, particularly using H1 and H5 hardening methods. When no hardening was done, 'Red Tsar' produced about twice the total and marketable fruit yields as 'PapriKing'. However, with hardening method H1 (withholding water during the last two weeks prior to transplanting), which is currently the recommended practice, 'PapriKing' produced about twice the total and marketable fruit yield as 'Red Tsar' (Figures 3 and 4). With hardening methods H2 and H3 'Red Tsar' produced slightly higher total and marketable yields than 'PapriKing', which produced more marketable yields with hardening methods H4 and H5.

Figure 3: Interaction between hardening method and cultivar on paprika total fruit yield at Harare, Zimbabwe, in 2000/01 season



Explanation see Figure 2

**Figure 4:** Interaction between hardening method and cultivar on paprika marketable fruit yield at Harare, Zimbabwe in 2000/01 season



Explanation see Figure 2

### DISCUSSION

The two main factors in this study, that is hardening method and cultivar, did not reflect any significant differences in terms of field establishment. Since transplanting causes the interruption of soil-root contact, root injury and post transplant shock, 'PapriKing' and 'Red Tsar' seedlings could have been similarly affected (Schultheis et al., 1988; Aloni, Pashkar and Karni, 1991). It is also a common observation that after transplanting, the transplants are affected by transplanting shock. The length of time until the resumption of rapid growth depends on environmental conditions but is also an inherited feature of each crop (Aloni, Daie and Karni, 1991). It appears that different crops have different capabilities to recover from transplanting shock and this is highly dependent on their ability to withstand root disturbance (Loomis, 1925). Trends in the current study suggest that interactions between the two cultivars and the hardening methods may be more important than the main effect with respect to field establishment. When seedlings were well-watered up to transplanting time, 'PapriKing', the widely available cultivar in Zimbabwe, performed much better than 'Red Tsar'. Field establishment of 'PapriKing' was more than twice that of Red Tsar. However, the two cultivars performed similarly with respect to field establishment when subjected to the other five moisture stress regimes. This result suggests that Red Tsar field establishment is enhanced under moisture stress. A similar result was reported by Delfine, Loreto and Alvino (2001), who suggested that bell peppers (cv 'Grossum Group') produced higher fruit yields when subjected to drought and temperature stress. On the other hand, 'PapriKing' is a stable cultivar, which does not drastically respond to changes in management techniques during the production of seedlings.

The fairly consistent performance of the two cultivars in terms of fruit yield after being subjected to some form of hardening (mild or extreme) makes both of these cultivars useful to smallholder (SH) farmers under a situation where water is limiting during the raising of seedlings in the nursery. In the SH sector, seedlings are invariably subjected to some degree of temperature and moisture stress while in the nursery (Chivinge and Mariga, 1998). Paprika cultivars that would respond positively to environmental stress or those whose yield performance remains stable after being subjected to such stress would be most ideal for use by SH farmers.

The rainfall situation in the 2000/01 season was more favourable than that in the 2001/02 season at Mukada. As could be observed, the low rainfall must have to a certain extent contributed to the low paprika fruit yields recorded on the Mukada trial in 2001/02 season. Besides, the pre-transplant moisture stress regimes administered in the nursery, the two cultivars could also have been subjected to reasonably high temperature in the seedbed and both temperature and moisture stress in

the field after transplanting, especially during the 2001/02 season at Mukada, where there was no supplementary irrigation. This continued stress could explain the drastic reduction in total and marketable yields at Mukada in 2001/02 when compared with the University of Zimbabwe trial, which was supplemented with irrigation. Other studies on the effects of drought stress on pepper growth have indicated that photosynthesis limitation becomes more permanent thus causing reduction in paprika yield (Batal and Smittle, 1981; Alvino et al., 1994; Delfine et al., 2001) while water stress during seedling growth affects bell pepper root growth as reported (Leskover and Cantliffe, 1992; Jaimez et al., 1999). Their studies showed that continuous watering increased root dry weight, basal root count and diameter compared with alternate watering which caused a decrease in these parameters. Seedlings which have higher root dry weight and thicker diameters have greater chances of success after transplanting.

## CONCLUSION

'Red Tsar' cultivar is more susceptible to posttransplant shock and thus sustains a higher mortality rate when its seedlings are not hardened before transplanting. Farmers would need to moderately harden paprika seedlings by withholding water during the last two weeks in the nursery in order to impart some degree of resistance to drought stress as this would allow them to withstand post-transplanting shock and impart good field establishment. In a situation whereby the farmer has no time to harden his/her seedlings in the nursery prior to transplanting, a cultivar such as 'PapriKing' would be a cultivar of choice.

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