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Effect of Seed Treatment on Wheat Seed Viability and Vigour

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Abstract

Use of farm-saved seed without treating encourage accumulation of seed borne pathogens which lead to outbreak and spread of diseases that result in poor emergence, crop stand, vigour, and reduction in yield. This study sought to determine the effect of seed treatment on viability and vigour. Seed samples of wheat varieties NjoroII, Robin and Eagle10 were treated with Murtano super® (20% Lindane and 26% Thiram), Seedplus® (10% Imidacloprid, 10% Metalaxyl, and 10% Carbendazim), Monceren® 125 DS (Imidacloprid 233g/L, Pencycuron 50g/L, Thiram 107g/L.), Rootgard®, (*Trichoderma* spp., *Bacillus* spp., *Pseudomonas* spp., *Aspergillus* spp., *Chaetomium* spp., *Esherichia* spp., *Azorobacter* spp.), Achook® (azadiractin 0.15%EC), Score 250 EC® (Difenoconazole 250g/L) and Thunder® (Imidacloprid 100g/L and Betacyfluthrin 45g/L). Untreated seeds were used as control. Germination was carried out on paper towel in the laboratory and on sterilized soil in the green house. Murtano super® improved germination of NjoroII by 0.5%, Seedplus® improved germination of Robin by 3.5% while Monceren® improved germination of Eagle10 by 4%. Score® and thunder® suppressed germination of NjoroII, Robin and Eagle10 by more than 50%, 30% and 20% respectively. All the treatments reduced seedling infections significantly. Seedplus, Murtano super and Achook significantly improved vigour indices of NjoroII, Robin and Eagle10 respectively. Seed treatments control seed borne diseases but some suppress germination and vigour. It is necessary to enhance farmers' awareness on the importance of seed treatment in order to improve germination, emergence and vigour and to prevent crop losses.

1. Introduction

Seed treatment plays an important role in managing seed borne pathogens responsible for diseases that affect seed germination, seedling emergence and growth of crops (Kay, 2012; Taha et al. 2013; Tegene et al., 2014; Akrami and Yousefi, 2015; Cardoso et al., 2016). Seed treatments are easy to apply and quite inexpensive with minimal environmental impact and minimal risks to non-target organism and these make it advantageous over other pest control measures (Hamid et al., 2013; Muthii, 2014). Most wheat farmers use recycled seed without treating and this could lead to accumulation of seed-borne pathogens which may cause seed abortion, seed rot, reduce seed germination and damage seedlings resulting in poor crop stand and reduction in yield (Perello et al., 2013; Keawkham et al., 2014).

The most commonly used treatments are Thiram, Carboxin, Captan, Carbendazim, Trichoderma spp., Vitavax® 200 (Carboxin + Thiram), Dividend® (Difenoconazole 92g/l + Metalaxyl 23g/l) (Shekhawat and Majumder, 2013; Keawkham et al., 2014; Sharma et al., 2015). These chemicals are available in form of wettable powders and liquid which are diluted with water and thoroughly mixed with seed to ensure uniform coverage. They contain fungicides, insecticides or a combination of the two (Sharma et al., 2015). Those with fungicidal properties protect seeds against fungal infections while those with insecticidal properties protect seed from insect pests (Aveling et al., 2013; Sharma et al., 2015). They are categorized as either systemic or contact based on their mode of action whereby systemic seed treatments are those absorbed and translocated within a plant tissue to destroy pathogens in the plant while contact seed treatments are those that are effective only on the surface of the seed (Rouabhi, 2010). Methods used in seed treatment include seed dressing that involves application of the treatment as either dry powder or in form of slurry, seed coating in which a blinder is used with a formulation to ensure the treatment adheres to the seed and seed pelleting in which application of the treatment causes a change in the physical shape of the seed intended to enhance handling and plantability (Sharma et al., 2015).

The success of seed treatments depends on the intrinsic effectiveness of the compound applied as well as the specificity and potential phytotoxicity of the treatments (Mancini and Romanazzi, 2014). Although chemicals can efficiently control plant diseases they can also have adverse effects, such as the development of fungicide-resistant species (Maketon et al., 2008). Some studies also show that ingredients in some systemic fungicides such as Captan fungicide as well as different concentrations of the ingredients used can inhibit growth characteristics of a plant (Dhanamanjuri et al., 2013). Other studies indicate that some seed treatments can cause reduction in germination and vigour due to phytotoxic effects (de Moraes Dan et al., 2012; Aveling et al., 2013; Rangwala et al., 2013; Cardoso et al., 2015). It is important that the treatments do not provide negative effects on viability and vigour and therefore, this study was carried out to determine the effect of seed treatments on wheat seed viability and vigour.

2. Materials and Methods

2.1. Experimental Materials

Table 1. *Trade name, active ingredients, application rate and properties of chemicals used to treat seeds of the three wheat varieties.*

Trade name	Active ingredient	Application rate	Properties
Murtano super®	20% Lindane, 26% Thiram	10 g /2 Kg seed	fungicides and insecticide active against rust, root rots and soil borne pests
Rootgard®	*Trichoderma* spp., *Bacillus* spp., *Pseudomonas* spp., *Aspergillus* spp., *Chaetomium spp., Esherichia spp., Azorobacter* spp.	50 g / 25 kg of seed	A biological product with insecticidal and fungicidal properties active against soil-borne diseases and pests such as root rots and damping off.
Thunder®	Imidacloprid 100g/L and Betacyfluthrin 45g/L	10 Ml / 20 L of water	Insecticide for the control of aphids.
Score® 250 EC	Difenoconazole 250g/L	15 Ml / 20 L of water	Fungicide for control of rust, leaf spot, powdery mildews and a scab.
Monceren® 125 DS	Imidacloprid 233g/l, Pencycuron 50g/l, Thiram 107g/l	10 Ml / 20 L of water	Fungicide active against root rots and damping off.
Achook®	azadiractin 0.15%EC	20 Ml / 20 L of water	Natural and botanical product with insecticidal properties
Seed plus®	10% Imidacloprid, 10% Metalaxyl, and 10% Carbendazim	10 g /2 Kg seed	Fungicides and insecticide active against rust, root rots and soil borne pests.

2.2. Experimental Site, Design and Layout

Laboratory and greenhouse experiments were carried out twice between March and May 2016 at the Faculty of Agriculture, University of Nairobi. Seven seed treatments presented in the table above and three wheat varieties (Njoro11, Robin and Eagle10) were used. The chemicals were mixed with sterile distilled water to make thick slurry. Seeds were mixed with the slurry by agitation in plastic bags till they were uniformly coated. Seeds were then air dried for 15 minutes before planting. In the laboratory, four replicates of 100 seeds were uniformly spread between wet paper towels. The experiment was set up at room temperature (21°C) in completely randomized design. In the Greenhouse experiment, 20 seeds of each variety were planted on sterile soil containing a mixture of forest soil/farm yard manure medium (2:1 v/v) and replicated four times (Musyimi *et al*., 2012). The experimental design was randomized complete block design in a split plot layout in which the main plot consisted of wheat varieties while the subplots consisted of the seed treatments (Kadaari, 2015). The plants were allowed to grow for a month during which emergence was assessed. Data collected was on the number of germinated seeds, mouldy seeds, hard seeds, normal seedlings, abnormal seedlings, seedlings with infection, root and shoot lengths, and seedling dry weight.

2.3. Determination of Germination, Emergence and Vigour

Germination in the laboratory was determined by counting the number of germinated seeds, mouldy seeds, hard seeds, normal, abnormal and infected seedlings two days after germination and at the same interval for ten days (Khan *et al*., 2015; Faligowska *et al*., 2016). A seed was considered mouldy if it had fungal mycelium on its surface while a hard seed was any seed that failed to germinate without infection and remained hard at the end of the experiment (Patil e*t al*., 2008). A normal seedling was any seedling that had all the morphological structures well developed and healthy or with slight defects or secondary infections on the morphological structures while an abnormal seedling was a seedling that did not show the potential to develop into a normal plant when grown, for instance, damaged, deformed or decayed seedlings (Ehiagbonare *et al*., 2008). A seedling with infection was either normal or abnormal and was considered abnormal if it was decayed as a result of primary infection so that normal development was prevented and the infection was determined by visual examination of the seedlings to identify disease symptoms such as discoloration.

Vigour index was determined by measuring the seedling length of 10 randomly selected seedlings and calculated using the formula below: (Oshone *et al*., 2014; Khan *et al*., 2015).

$$\text{Vigour index} = \text{Seedling Length x germination percentage}$$

Emergence in the green house was determined by counting the number of emerged seedlings four days after emergence and at an interval of two days for 14 days. Seedling dry weight was determined by drying 10 randomly selected seedlings in an oven at 65°C for 48 hours (Afrakhteh *et al*., 2013; Sibande *et al*., 2015). Vigour index was calculated using the following formula:

Vigour index = germination percentage x seedling dry weight (Oshone *et al*., 2014)

2.4. Data Analysis

Data was subjected to analysis of variance (ANOVA) using GENSTAT version 15.0 and means separated using Fisher's protected test at 5% significance level (Steel *et al.*, 1997).

3. Results

There was significant variation (P≤0.05) in germination of the three varieties across the different treatments (Table 2). Some treatments enhanced germination while others delayed germination. Highest variation was observed on the first day of evaluation at which Seedplus increased germination of NjoroII and Robin by 38% while Murtano super increased germination of Eagle10 by 25.1%. At the same time, Thunder delayed germination of NjoroII and Robin by 32.4% and 41.5% respectively while Score delayed germination of Eagle10 by 55.5%. Germination increased over time with less variation among the treatments. The effect of the treatments among the varieties did not vary but germination of the varieties was different with highest germination being observed in Eagle10.

Table 2. *Percentage germination of three wheat varieties treated with different seed treatments evaluated at different times in the laboratory*

Treatments/ Varieties	Days after planting					Mean
	2	4	6	8	10	
NjoroII						
Seedplus®	71.0a	86.0b	90.0a	90.5a	90.5a	85.6a
Murtano super®	62.5b	62.6b	89.5a	92.5a	92.5a	79.0b
Rootgard®	31.5cd	89.0a	89.0a	89.0a	89.0a	77.5b
Monceren®	23.5d	92.0a	92.0a	92.0a	92.0a	78.3b
Achook®	13.0e	80.5c	80.5b	82.0b	83.0b	67.8c
Score®	1.6f	14.5e	18.0c	22.0c	25.0c	16.2d
Thunder®	0.6f	16.0e	18.5c	24.0c	26.0c	17.0d
Control	33.0c	89.0a	92.0a	92.0a	92.0a	79.6b
LSD (p≤0.05)	8.0	4.4	6.4	5.9	5.7	4.6
CV (%)	18.6	5.0	6.1	5.6	5.3	5.0
Robin						
Seedplus®	83.5a	97.5a	97.5a	97.5a	97.5a	95.1a
Murtano super®	65.5b	92.6a	96.5a	96.5a	96.5a	89.1b
Rootgard®	52.0c	97.0a	97.0a	97.0a	97.0a	88.0b
Achook®	30.6d	97.5a	97.5a	97.5a	97.5a	84.1bc
Monceren®	19.5e	92.6a	95.0a	95.0a	95.0a	79.2c
Score®	5.0f	30.6c	39.0c	43.0c	48.0c	33.1e
Thunder®	4.0f	41.0b	55.0b	61.0b	64.5b	45.1d
Control	45.5c	96.5a	96.5a	96.5a	96.5a	86.3b
LSD (p≤0.05)	8.3	6.3	5.9	8.3	6.5	5.5
CV (%)	14.9	5.4	4.8	6.7	5.2	5.1
Eagle10						
Murtano super®	88.6a	96.0a	97.5a	97.5a	97.5a	95.3a
Seedplus®	87.5a	97.5a	97.5a	97.5a	97.5a	95.4a
Rootgard®	74.0b	94.6a	96.0a	96.5a	97.5a	91.7ab
Monceren®	62.5c	95.0a	95.0a	98.0a	98.0a	89.7b
Achoock®	33.5d	93.5a	93.5a	93.5a	93.5a	81.5c
Thunder®	16.6e	65.0b	73.5b	75.5b	77.5b	61.6d
Score®	8.0f	55.0c	62.6c	66.0c	68.5c	52.0e
Control	63.5c	92.5a	94.5a	94.5a	94.5a	87.9b
LSD (p≤0.05)	8.0	5.3	5.8	5.3	5.9	5.0
CV (%)	10.2	4.2	4.5	4.0	4.5	4.1

Means followed by the same letter(s) in each column are not significantly different at p≤0.05, LSD= Least significant difference, CV= coefficient of variation

The effect of the treatments on emergence of the three varieties also varied significantly (P≤0.05) and was different compared to germination in the laboratory (Table 3). On the first day of evaluation, Rootgard treated seeds of NjoroII and Robin registered the best emergences which were an increase of 8.5% and 7.5% respectively while Score reduced emergence of the same varieties by 47.5% and 66.5% respectively. Monceren was the best in Eagle10 by improving emergence by 8.8% while Score reduced the emergence by 42.5%. Emergence increased with increase in time for the first six days. There was no variation on the effect of the treatments among the varieties.

Table 3. *Percentage emergence of three wheat varieties treated with various seed treatments evaluated at different times in the green house*

Treatments/ Varieties	Days after planting				Mean
	4	6	8	10	
NjoroII					
Rootgard®	76.3a	77.5a	83.8a	83.8a	80.3a
Monceren®	72.5a	78.8a	85.0a	85.0a	80.3a
Murtano super	68.8a	71.3ab	76.3a	76.3a	73.1a
Seedplus®	62.5a	65.0ab	78.8a	78.8a	71.3a
Achook®	35.0b	50.0bc	48.8b	48.8b	45.6b
Thunder®	23.8b	30.0c	35.0b	35.0b	30.9b
Score®	20.0b	30.0c	42.5b	42.5b	33.8b
Control	67.5a	75.0ab	77.5a	77.5a	74.4a
LSD (p≤ 0.05)	21.03	24.22	17.31	17.31	18.6
CV (%)	27.0	27.8	18.0	18.0	20.8
Robin					
Rootgard®	91.3a	91.3a	92.5a	92.5a	91.9a
Seedplus®	90.0a	90.0a	90.0a	90.0a	88.8a
Murtano super®	86.3a	90.0a	91.3a	91.3a	88.1a
Monceren®	80.0a	81.3ab	87.5a	87.5a	84.1a
Achook®	56.3b	68.8b	73.8b	73.8b	68.1b
Thunder®	27.5c	33.8c	38.8c	38.8c	34.7c
Score®	16.3c	22.5c	33.8c	33.8c	26.6c
Control	83.8a	85.0ab	91.3a	91.3a	86.6a
LSD (p≤ 0.05)	13.55	15.9	12.79	12.79	12.5
CV (%)	14.0	15.5	11.7	11.70	12.0
Eagle10					
Monceren®	81.3a	82.5a	83.8a	83.8a	81.3a
Achook®	77.5a	83.8a	86.3a	86.3a	83.4a
Rootgard®	76.3a	80.0a	82.5a	82.5a	80.3a
Murtano super®	72.5a	78.8a	80.0a	80.0a	77.8a
Seedplus®	71.3a	76.3a	85.0a	85.0a	78.1a
Thunder®	70.0a	75.0a	77.5a	77.5a	75.0a
Score®	30.0b	38.8b	51.3b	51.3b	42.8b
Control	72.5a	76.3a	80.0a	80.0a	75.3a
LSD (p≤ 0.05)	15.57	15.24	13.01	13.01	12.2
CV (%)	15.50	14.10	11.40	11.40	11.3

Means followed by the same letter(s) in each column are not significantly different at p≤0.05, LSD= Least significant difference, CV= Coefficient of variation

There was significance difference (P≤0.05) in the percentage of normal seedlings of the three varieties across the treatments (Table 4). NjoroII treated with Murtano super registered the highest percentage of normal seedlings. Seedplus and Achook recorded the best performance on variety Robin by improving the percentage of normal seedlings by 3.5% while Monceren was the best on Eagle10, improving the percentage of normal seedlings by 4%. Score negatively affected all the varieties by reducing the level of normal seedlings by 67.5% in NjoroII, 46% in Robin and 25.5% in Eagle10. There was no variation on the effect of the treatments on the different varieties.

Significance difference (P≤0.05) was also noted in the percentage of abnormal seedlings across the treatments. Seedplus, Monceren, Score, Achook and Murtano super reduced the amount of abnormal seedlings in NjoroII and Robin by 3.5% and 3% respectively while Thunder increased the same by 2% and 2.5% respectively. In Eagle10, all the treatments except Thunder reduced the level of abnormal seedlings by 0.5%. Thunder recorded an increase of 4.5% of the abnormal seedlings. The percentage of hard seeds was also significantly different (P≤0.05) across the treatments. On NjoroII, Rootgard reduced the level of hard seeds by 0.5% while Score increased the level of hard seeds by 74%. On Eagle10, Seedplus reduced the level of hard seeds by 0.5% while Score increased the level by 31%.

All the treatments significantly (P≤0.05) reduced the level of seedling infection in all the varieties. The results indicated that Achook, Score and Thunder were the most effective treatments in controlling seedling infection in NjoroII by lowering the infection level by 17% as compared to Rootgard which reduced the infection level by only 3.5%. On Robin, Murtano super, Monceren, Score and Thunder lowered the infection level by 10.5% while Seedplus reduced the infection level by only 1%. Eagle10 recorded best results with Score and Thunder which reduced the infection levels by 10.5% while Seedplus lowered the infection level by only 2.5%. There was also variation in the infection levels among the varieties with NjoroII recording the highest percentage of the seedling infection.

Table 4. *Percentage viability and infection of three wheat varieties across different seed treatments in the laboratory.*

Treatments / Varieties	Viability				Infection	
	Germinated seeds	Normal seedlings	Abnormal seedlings	Hard seeds	Mouldy seeds	Infected seedlings
Njoro 11						
Rootgard®	89.0a	88.0ab	1.0c	0.5b	10.5a	13.5b
Seedplus®	90.5a	90.5a	0.0c	4.5b	5.0b	5.5c
Monceren®	92.0a	92.0a	0.0c	3.0b	5.0b	5.5d
Score®	25.0c	25.0c	0.0c	75.0a	0.0c	0.0e
Thunder®	26.0c	20.5c	5.5a	74.0a	0.0c	0.0e
Achook®	83.0b	83.0b	0.0c	3.5b	13.5a	0.0e
Murtano super®	92.5a	92.5a	0.0c	2.5b	2.5ab	6.0d
Control	92.0a	92.0a	3.5b	1.0b	5.5b	17.0a
LSD (p≤0.05)	5.7	5.7	1.7	4.2	3.5	2.3

Treatments / Varieties	Viability				Infection	
	Germinated seeds	Normal seedlings	Abnormal seedlings	Hard seeds	Mouldy seeds	Infected seedlings
CV (%)	5.3	5.4	95.2	14.1	46.0	24.3
Robin						
Rootgard®	97.0a	96.0a	1.0c	0.0c	3.0b	6.5b
Seedplus®	97.5a	97.5a	0.0c	0.5c	2.0bc	9.5a
Monceren®	94.5a	94.5a	0.0c	5.0c	0.5cb	0.0c
Score®	48.0c	48.0c	0.0c	52.0a	0.0e	0.0c
Thunder®	64.5b	59.0b	5.5a	35.5b	0.0e	0.0c
Achook®	97.5a	97.5a	0.0c	1.0c	1.5de	2.5c
Murtano super®	96.5a	96.5a	0.0c	3.5c	0.0e	0.0c
Control	96.5a	94.0a	3.0b	0.0c	3.5a	10.5a
LSD (p≤0.05)	6.5	6.4	1.8	6.5	1.1	2.6
CV (%)	5.2	5.1	101.7	36.7	56.1	49.1
Eagle 10						
Rootgard®	97.5a	97.0a	0.0b	1.0c	2.5b	5.0c
Seedplus®	97.5a	97.5a	0.0b	0.0c	2.5b	8.0d
Monceren®	98.0a	98.0a	0.0b	2.0c	0.0c	0.5a
Score®	68.5c	68.5b	0.0b	31.5a	0.0c	0.0a
Thunder®	77.5b	72.5b	5.0a	22.5b	0.0c	0.0a
Achoock®	93.5a	93.5a	0.0b	0.5c	4.5a	3.5bc
Murtano super®	97.5a	97.5a	0.0b	2.0c	0.5c	1.0ab
Control	94.5a	94.0a	0.5b	0.5c	4.5a	10.5d
LSD (p≤0.05)	5.9	5.9	1.4	5.5	1.4	2.7
CV (%)	4.5	4.5	142.4	50.5	54.0	51.6

Means followed by the same letter(s) in each column are not significantly different at p≤0.05, LSD= Least significant difference, CV= Coefficient of variation, V1= NjoroII, V2= Robin, V3= Eagle10

Seedling length, dry weight and vigour index were significantly different (P≤0.05) across the seed treatments both in the laboratory and greenhouse (Table 5 and 6). In the laboratory, NjoroII treated with Seedplus had the highest increased seedling length and vigour index of 33% and 29% respectively while Score reduced the same by 25% and 79%. Robin recorded the highest increased seedling length and vigour index of 53% and 54% when treated with Murtano super and reduced seedling height and vigour index when treated with Monceren and Score while Eagle10 had the highest increased seedling height of 9% and vigour index of 7% when treated with Achook and reduced seedling length and vigour index when treated with Score.

In the greenhouse, similar results were observed on NjoroII and Robin on which Seedplus proved to be the most effective treatment by improving the dry weight and vigour index of NjoroII by 40% and 34% respectively while Murtano super was the most effective on Robin, increasing the dry weight by 53% and vigour index by 62%. Seedplus also recorded the best performance on seeds of variety Eagle by increasing the dry weight by 5% and vigour index by 9%. The least effective treatments were Score and Monceren. Score reduced the dry weights of NjoroII and Robin by 17% and 4%, and vigour index by 51% and 59% while Monceren reduced the dry weight of Eagle10 by 28% and vigour index by 29%. The effects of the treatments on the different varieties was also different, for instance, Seedplus improved the dry weights of NjoroII by 40% and that of Robin by 16% only.

Table 5. *Seedling length and vigour index of three wheat varieties across different seed treatments (Laboratory experiment).*

Treatments	Seedling length			Vigour index		
	NjoroII	Robin	Eagle10	NjoroII	Robin	Eagle10
Seedplus®	35.7a	18.4c	30.1c	32.0a	18.0c	29.3c
Rootgard®	32.0b	15.7d	31.2bc	28.4b	13.9e	30.6b
Thunder®	31.0bc	14.1e	24.6e	8.4e	9.2g	19.1e
Monceren®	30.3bc	10.9f	27.3d	27.7c	10.0f	26.7d
Achook®	30.2bc	20.1b	34.2a	24.9d	19.5b	31.8a
Murtano super®	29.3c	25.1a	27.1d	26.9c	24.2a	26.2d
Score®	20.0e	11.3f	17.6f	5.1f	5.3h	12.0f
Control	26.8d	16.4d	31.5b	24.8d	15.7d	29.7bc
LSD (p≤0.05)	2.0	1.0	1.2	1.1	0.7	1.1
CV	2.9	2.7	1.9	2.1	2.2	1.9

Means followed by the same letter(s) in each column are not significantly different at p≤0.05, LSD= Least significant difference, CV= coefficient of variation

Table 6. *Dry weight and vigour index of three wheat varieties treated with various seed treatments (Greenhouse experiment)*

Treatment	Dry weight			Vigour index		
	NjoroII	Robin	Eagle10	NjoroII	Robin	Eagle10
Seedplus®	15.1a	12.2b	14.8a	11.4ab	10.8b	12.8a
Rootgard®	13.3b	12.1b	11.4c	10.8b	11.1b	9.1e
Thunder®	9.9de	10.3c	14.3a	3.7e	4.0d	11.1cd
Monceren®	14.8a	15.9a	10.1d	12.3a	14.3a	8.3e
Achook®	11.1c	11.1bc	14.4a	5.9d	8.4c	12.4ab
Murtano super®	11.0cd	16.1a	12.8b	8.8c	14.9a	10.5d
Score®	9.0e	10.1c	10.8cd	4.2e	3.8d	5.8f
Control	10.8cd	10.5c	14.1a	8.5c	9.2c	11.7bc
LSD ($p \leq 0.05$)	1.1	1.4	1.1	1.1	1.1	0.8
CV	3.9	5.1	3.6	6.0	5.1	3.6

Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$, LSD= least significant difference, CV= coefficient of variation

4. Discussion

Most treatments improved germination percentage of the three varieties. Emergence of the varieties in the greenhouse was also improved. These findings concur with those of De Villiers *et al*. (2006), Aveling *et al*. (2013), Taye *et al*. (2013) and Patil *et al*. (2015) which stated that seed treatments improved germination of maize, canola and chickpea seeds while others delayed germination. Findings by Masum *et al*. (2009), Oyekale *et al*. (2012), Sivparsad *et al*. (2014) and Patil *et al*. (2015) showed that the use of seed treatments had positive effect on germination percentage of sesame and chickpea seeds. Increase in germination was also noted in bean and maize seeds treated with *Trichoderma* spp and in coriander seeds treated with Carbendazim (Okoth *et al*., 2011). De Villiers *et al*. (2006) and Taye *et al*. (2012) reported variation among pre-sowing fungicide seed treatments on canola seeds in South Africa and maize seedlings in Kenya respectively while findings by Muthomi *et al*. (2007), Allah, 2010 and Kadaari, (2015) revealed that use of seed treatments improved emergence of maize and bean seeds. On the contrary, Aveling *et al*. (2013) reported that no seed treatment resulted to reduction in germination of maize seed under laboratory conditions while Cardoso *et al*. (2015) found no difference in germination of broccoli treated with Carboxin and Thiram. Most treatments increased seedling lengths, dry weights and vigour indices while a few resulted in reduction of the same parameters. Similarly, Govindappa *et al*. (2011); Jamadar and Chandrashekar, (2015) and Patil *et al*. (2015) reported increased vigour index in treated seeds of tomato, rice, castor and chickpea seeds while Bittencourt *et al*. (2000) and Fessel *et al*. (2003) observed decreased vigour index in maize seedlings caused by chemical seed treatments. On the contrary, Tavares *et al*. (2007) reported that vigour index of bean varieties were not affected by seed treatments while Aveling *et al*. (2013) found that some seed treatments containing Metalaxyl did not negatively affect vigour of maize seeds.

Variation in germination could be attributed to variation in chemical composition of the treatments as well as the concentration of specific active ingredients since some treatments have similar active ingredients but different application rates. Tort *et al*. (2006) reported that seed treatments do not reduce germination when used at the recommended dosage. Increase in germination percentage may be due to reduction in disease infection within the seed while decline in germination percentage could be attributed to decline in synthetic activity of the embryo due to toxicity by the chemicals (Praveen *et al*., 2010). Higher germination is an indication that the treatment protected the seedling against adverse conditions such as phytopathogens (Taye *et al*., 2013). The difference in emergence could be attributed to varied effectiveness of the seed treatments in controlling soil borne diseases. Reduction in emergence as a result of some treatments could be due to increased application rates of fungicide in the soil that favours disease development or causes phytotoxic effects that impairs physiological quality of the seed (Petch *et al*., 1991; Cardoso *et al*., 2016). Decrease in vigour index may be attributed to phytotoxic effect of the chemicals which prevents physiological and metabolic activities of the plant (de Moraes Dan *et al*., 2012: Cardoso *et al*., 2016). Association of phytopathogens with seeds can severely affect their quality, reducing their germination potential, vigor, emergence, crop stand and even their yield (Marroni *et al*. 2012). Coating healthy seeds with fungicides has been effective in reducing severity of pathogens (Scherm *et al*., 2012). Performance of a seed in terms of both viability and vigour is also a consequence of an interaction between seed vigour and prevailing conditions such as sowing depth, soil moisture, soil temperature and salinity (Rajala *et al*., 2011). Salinity, for instance, affects germination of seeds by either creating an osmotic potential outside the seed thereby preventing water intake or through toxic effects of Sodium and Chlorine ions on the germinating seed (Khomari *et al*., 2014). Rootgard® and Seedplus® which recorded highest emergence contain Thiram, *Trichoderma spp.* and Carbendazim which promote development of stronger roots by controlling pathogens (Jamadar and Chandrashekhar, 2015) and increase uptake of nutrients by secreting plant growth regulatory factors like phytohormones and release of soil nutrients and minerals by the activity of saprophytic organisms in soil (Colla *et al*., 2015).

All the treatments were effective in reducing seed-borne infections with Thunder® and Score® being the most effective. Masum *et al*. (2009) and Gaurilcikiene *et al*. (2012) also indicated that seed treatments are important in controlling seed borne infections in wheat and pea and that the effect of seed treatments varies. The variation could be attributed to variation in effectiveness of the compound applied and phytotoxicity of the active ingredients in the treatments (Mancini and Romanazzi, 2014). Reduction in seedling infection could be due to the ability of the treatments to reduce the primary source of disease inoculum in the seeds (Amare *et al*., 2014).

5. Conclusion and Recommendations

Germination, emergence and vigour of the wheat seeds were affected by the treatments. Seedplus®, Murtano super®, Rootgard®and Monceren® improved germination and emergence while Score® and Thunder® delayed the germination and emergence. Score® and Thunder® also resulted in least vigour indices across all the varieties. The treatments exhibited different effects on the seeds of the three varieties in terms of both germination and emergence. Murtano super® treated seeds of NjoroII and Eagle10, and Seedplus® treated seeds of Robin had the best germination. Monceren®, Rootgard® and Achook® resulted in best emergence among treated seeds of NjoroII, Robin and Eagle 10 respectively. All the seed treatments reduced seedling infection across all the varieties. It is important to enhance farmers awareness on the importance of seed treatment in order to improve germination, emergence, vigour and to reduce incidences of seed and soil borne diseases.

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