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Sultan Singh
Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Virender Singh Mor
Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Axay Bhuker
Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Rahul Kumar
Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Gagandeep Singh
Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Digamber
Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Corresponding Author:
Sultan Singh
Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

Evaluating the effect of various seed treatment approaches on seed quality of wheat (*Triticum aestivum* L.)

Sultan Singh, Virender Singh Mor, Axay Bhuker, Rahul Kumar, Gagandeep Singh and Digamber

Abstract
The quality of seeds is a critical factor in crop establishment and has a substantial influence on overall production and productivity. Seed treatment is used to manage seed-borne pathogens, insects and pests which can directly impact seed quality, germination, and vigor. This study was conducted during 2018 to 2020 at the Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University in Hisar, aimed to assess the influence of pesticide and biofertilizer treatments on the seed quality of wheat varieties (WH1105 and WH1124). The results revealed that seeds treated with *Azotobacter* exhibited improved seed quality across various parameters. The maximum speed of germination was recorded in treatment T_6-Chlorpyrifos+*Azotobacter* and the germination percentage, seedling length, seedling dry weight, vigor indicex-I, vigor index-II, field emergence index and seedling establishment all these parameters were recorded highest with treatment T_3-*Azotobacter*. Chlorpyrifos had a detrimental effect on seed quality when treated as individual along with different combinations. Furthermore, the performance of WH1124 was better than WH1105 in different parameters. These findings suggest that biofertilizers enhance seed quality, whereas the insecticides and fungicides have a deleterious influence on seed quality.

Keywords: *Azotobacter*, biofertilizers, seed quality, seed treatments, wheat

Introduction
Wheat is an annual crop that belongs to the Poaceae family and is believed to have originated in South West Asia (Jenkins, 1966) [12]. This crop played an indispensible role in ushering the "Green Revolution" in many developing countries including India. Globally, wheat annual production is 802.1 million tons recorded in 2022-23 (FAO, 2023) [8]. In India, total cultivated area of wheat is 31.86 million hectares in 2022-23 (DAFW, 2023) [3] which produces 109.52 million tons of grains and shares 13% of total wheat production of the world (Singh *et al.*, 2023) [20]. Seed is the most fundamental input required to sustain agriculture. Therefore, it is imperative to develop a cheap and eco-friendly seed production technology, which produces good quality seeds. Seed treatment is a prudent pest-management tactics, are becoming increasingly important as IPM-compatible measures. The process of treating seeds to provide the necessary nutrients and prevent pests and diseases involves the application of both beneficial microbes and chemical pesticides. In India, insect pests are responsible for 15.7 percent yield losses in wheat, (Dhaliwal *et al.*, 2015) [6].
Currently, the agriculture has become heavily relied on cost-intensive crop inputs such as inorganic fertilizers and pesticides (Das and Mandal, 2015) [4]. The use of chemical fertilizers in agriculture is reduced by biofertilizers. The biofertilizers never pollute the land, water, or air (Tamilkodi and Victoria, 2018) [21]. Biofertilizers are elements that comprise a multiplicity of microbes that have the capability to enhance plant nutrient uptake by colonizing the rhizosphere and making nutrients readily available to plant root hairs. Biofertilizers are rated as the one of most promising alternatives to chemical fertilizer application. *Azospirillum, Azotobacter, Azola,* blue-green algae, Phosphate solubilizing microorganisms, sinorhizobium, and mycorrhizae are among the most prominent microorganisms that function as effective biofertilizers (Me Carty *et al.*, 2017) [17]. These key soil-inhabiting microorganisms perform nitrogen fixation for plants, solubilization of potassium and phosphorus reserves in soil (Gupta *et al.*, 2012; Meena *et al.*, 2016; Hamid and Bashi, 2019) [9, 16, 10]. The *Azotobacter* is responsible for nitrogen fixing in soil, while the phosphate solubilizing bacteria is responsible for solubilizing phosphorus in soil.

The present study was commenced, taking into consideration that seed treatment serves as an environmentally friendly and cost-effective method to achieve both quality and sustainability in high-quality wheat seed production.

Materials and Methods

Experimental site

The experiments were carried out between 2018 and 2020 in the laboratories and research farm of the Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, situated in the semi-tropical region in the western zone of India.

For the experiment, wheat seed cultivars WH1105 and WH1124 along with one-year-old harvested seeds and freshly harvested seed lots for each variety were used. The seeds were primed with Chlorpyrifos 20EC (1.5 ml/kg of seeds), Vitavax (2g/kg of seeds), *Azotobacter* (5 ml/kg of seeds), and their combinations of total 8 treatments including control as shown in table 1 and important properties of treatments are mentioned in table 2. By using 10% jaggery solution, the biofertilizer stickiness on seed surface was significantly improved and then keeps the treated seeds under shade for a while. After that treated seeds were packed in plastic zipped bags.

Table 1: Their combinations of total 8 treatments including control

Treatments	Concentrations
T_0	Control
T_1	Chlorpyrifos 20EC
T_2	Vitavax
T_3	*Azotobacter*
T_4	Vitavax+Chlorpyrifos
T_5	Vitavax+*Azotobacter*
T_6	Chlorpyrifos+*Azotobacter*
T_7	Chlorpyrifos+Vitavax+*Azotobacter*

Table 2: Important properties of treatments

Active ingredient	Application rate	Properties
Chlorpyrifos 20EC	1.5 ml/kg of seeds	Insecticides for the control of termites
Vitavax	2 g/kg of seeds	Broad spectrum, dual action (systemic and contact) fungicide which controls seed and soil borne diseases.
Azotobacter	5 ml/kg of seeds	Improve plant health through nitrogen fixation, growth hormone production, phosphate solubilization, plant disease management

The following methodology employed for recording various observations are given below:

For speed of germination, three replications of 100 seeds each were placed in petri-plates for germination (Top of paper method). The numbers of radicle emergence were counted on daily basis. The index of the speed of germination was calculated by formula as cited by Maguire (1962) [14].

$$\text{Speed of germination} = \frac{n_1}{d_1} + \frac{n_2}{d_2} \ldots + \frac{n_n}{d_n}$$

Where,

n = number of newly emerged radicle on a respective day

d = days after sowing up to the emergence of the radicle

In the laboratory, three replications of 100 seeds were uniformly placed in between wet paper. The samples were placed in a germinator at a temperature (20°C) in a completely randomized design. For between paper methods, the final count was observed on the 8th day as per ISTA (2011) [11]. Data collected on the basis of number of germinated seeds, normal seedlings, seedling length, seedling dry weight, vigor index-I, vigor index-II, field emergence index and seedling establishment as recommended by ISTA (2011) [11]. The final count day after germination is used to collect data for the germination percentage by counting the number of germinated seeds, normal seedlings, abnormal seedlings, hard seeds, and infected seedlings.

$$\text{Standard Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds kept for germination}} \text{X}100$$

From each replication of all the genotypes, thirty normal seedlings were chosen at random, and their length was measured in cm. The average length of these seedlings was calculated. For determining seedling dry weight, we used the same thirty healthy seedlings from each replication that were measured for seedling length. These seedlings were dried in a hot air oven for one day (24 hours) at a temperature of 80±1 °C. Before taking the seedling dry weight, we allowed it to equilibrate in a desiccator for at least 20 minutes. Seedling vigor indices were calculated by using the formula given by Abdul-Baki and Anderson (1973) [1] and expressed as the whole numbers.

Seedling vigor index-I = Germination percentage × Average seedling length (cm)

Seedling vigor index-II = Germination percentage × Average seedling dry weight (mg)

For the observation of field parameters i.e. field emergence index, hundred seeds of all the treatments in three replications in Randomized Block Design (RBD). The number of seedling emerged out of soil were counted daily up to the seedling establishment. Field emergence index was calculated using formula as:

$$\text{Field Emergence Index (FEI)} = \frac{\text{No.of seedling emerged}}{1^{st}\text{ day of sowing}} + \ldots\ldots + \frac{\text{No.of seedling emerged}}{\text{Day of the last count}}$$

The seedling establishment was determined when the total number of seedlings emerged i.e. there was no more addition in the total emerged seedlings.

Statistical analysis

Statistical analysis of data collected during the study was done by using the factorial complete randomized design as

described by Panse and Sukhatme (1985) [18]. All the values described as mean of the replicates with the evaluation of CD at 5% level of significance by using software OPSTAT.

Results and Discussion

The use of chemical fertilizers and pesticides causes the unfavorable impact on the environment. Extensive research was carried out to minimize the use of chemical fertilizers and improve soil fertility status and enhancing the crop production by their biological activity in the rhizosphere. The effect of various seed treatment *viz. Azotobacter*, Chlorpyrifos and Vitavax are analyzed on speed of germination, germination percentage, seedling length, seedling dry weight, vigor index-I, vigor index-II, field emergence index and seedling establishment of wheat. The seed quality parameters bear up the performance of the wheat seed of WH1105 and WH1124 of both the old and fresh seed lots.

The mean performance specifically to the lots and the varieties of WH1105 and WH1124 are cited in table (3, 4, 5 and 6). The mean performance of speed of germination precisely to the lots and the varieties of WH1105 and WH1124 is cited in table 3. The highest speed of germination was recorded in T_6-Chlorpyrifos+*Azotobacter* (57.97) followed by T_3-*Azotobacter* (53.49), while the lowest was observed in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (46.06) as compared to T_0-control (46.36) in WH1105. The same trend was recorded in WH1124 *i.e.*, the maximum speed of germination observed in T_6-Chlorpyrifos+*Azotobacter* (58.09) followed by T_3-*Azotobacter* (55.18), while the minimum speed of germination was recorded in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (48.01) as compared to T_0-control (49.94). From the second day, treatment T_6-Chlorpyrifos+*Azotobacter* had begun to show their impact on embryo protrusion. It might be due to the Chlorpyrifos used as solute and water as a solvent to make a solution for treatment to the seed and that solvent (water) helps to seed for early embryo protrusion along with the impact of biofertilizers for providing the required nutrient to seed.

In WH1105, the maximum enhancement of germination was observed in treatment T_3-*Azotobacter* (93.67%) which was at par with T_5-Vitavax+*Azotobacter* (91.00%) and minimum was in T_1- Chlorpyrifos (84.67%) as compared to T_0-control (89.00%). The similar trend was observed in WH1124 *i.e.*, the maximum germination was observed in T_3-*Azotobacter* (94.83%) followed by T_5-Vitavax+*Azotobacter* (91.67%) and was minimum in T_1-Chlorpyrifos (85.67%) as compared to T_0-control (90.17%) mentioned in table 4. These findings confirm the results of Biswas *et al.* (2015) when *Azotobacter* was utilized as seed treatment and in conjunction with soil application of *A. chroococum*.

The mean performance of seedling length precisely to the lots and the varieties of WH1105 and WH1124 is shown in figure 1. In WH1105, the maximum seedling length was observed in treatment T_3-*Azotobacter* (31.39 cm), at par with T_6-Chlorpyrifos+*Azotobacter* (28.68 cm) and minimum seedling length was in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (25.24 cm) as compared to T_0-control (26.43 cm). In WH1124, the highest seedling length was observed in T_3-*Azotobacter* (31.90 cm) followed by T_6-Chlorpyrifos+*Azotobacter* (29.38 cm) and lowest seedling length was in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (25.94 cm) as compared to T_0-control (27.02 cm). These findings confirm the results of Singh and Prasad (2011) in wheat. The mean performance of seedling dry weight specifically to the lots and the varieties of WH1105 and WH1124 is presented in figure 2. In WH1105, the maximum seedling dry weight was observed in treatment T_3-*Azotobacter* (14.18 mg), at par with T_6-Chlorpyrifos+*Azotobacter* (13.07 mg) and minimum seedling dry weight was in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (11.32 mg) as compared to T_0-control (11.82 mg). In WH1124, the highest seedling dry weight was observed in T_3-*Azotobacter* (14.44 mg) followed by T_6-Chlorpyrifos+*Azotobacter* (13.27 mg) and lowest seedling dry weight was in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (11.75 mg) as compared to T_0-control (12.24 mg).

The mean performance of vigor index-I specifically to the lots and the varieties of WH1105 and WH1124 is mentioned in table 5. The maximum vigor index-I was observed in treatment T_3-*Azotobacter* (2942), followed by T_5-Vitavax+*Azotobacter* (2559) and minimum was in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (2163) as compared to T_0-control (2355) in WH1105. The similar trend was observed in WH1124 *i.e.*, the highest vigor index-I was observed in T_3-*Azotobacter* (3027) followed by T_5-Vitavax+*Azotobacter* (2654) and was lowest in T_1-Chlorpyrifos (2238) as compared to T_0-control (2238). The mean performance of vigor index-II precisely to the lots and the varieties of WH1105 and WH1124 is cited in table 6. The highest vigor index-II was recorded in T_3-*Azotobacter* (1330) followed by T_6-Chlorpyrifos+*Azotobacter* (1158), while the lowest was observed in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (971) as compared to T_0-control (1053) in WH1105. The same trend recorded in WH1124 *i.e.*, the maximum vigor index-II was observed in T_3-*Azotobacter* (1371) followed by T_6-Chlorpyrifos+*Azotobacter* (1188), while the minimum vigor index-II was recorded in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (1016) as compared to T_0-control (1105). Kumar *et al.* (2018) [13] confirms the results of seedling length, seedling dry weight, vigor index I and vigor index II in maize crop.

The mean performance of field emergence index specifically to the lots and the varieties of WH1105 and WH1124 is revealed in figure 3. In WH1105, the maximum field emergence was observed in treatment T_3-*Azotobacter* (8.58), at par with T_2-Vitavax (7.91) and minimum was in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (4.58) as compared to T_0-control (6.07). The similar trend was observed in WH1124 *i.e.*, the highest field emergence index was observed in T_3-*Azotobacter* (8.79) followed by T_2-Vitavax (8.03) and was lowest in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (4.69) as compared to T_0-control (6.48). The mean performance of seedling establishment precisely to the lots and the varieties of WH1105 and WH1124 is shown in figure 4. In WH1105, the maximum seedling establishment was observed in treatment T_3-*Azotobacter* (87.84), at par with T_2-Vitavax (84.17%) and minimum seedling establishment was in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (77.17%) as compared to T_0-control (81.50%). In WH1124, the highest seedling establishment was observed in T_3-*Azotobacter* (88.84%) followed by T_2-Vitavax (84.84%) and lowest seedling establishment was in T_7-Chlorpyrifos+Vitavax+*Azotobacter* (78.33%) as compared to T_0-control (82.50%).

The best results of germination percentage, seedling length, seedling dry weight, vigor index-I, vigor index-II, field emergence index and seedling establishment were observed due to the seed treated with T_3-*Azotobacter*. Seed treatment of

only *Azotobactor* treatment recorded significantly highest among all parameters as compared to other treatments and combinations. It might be due to the biofertilizers helped the seed in mobilizing the essential nutritional elements from non-usable to usable form via biological processes and nitrogen fixing properties of bio inoculants along with the encouragement to seed for nutrient uptake as discussed by Me Carty *et al.* (2017) [17] in wheat by using *Azotobacter* and PSB. The outcomes and results were in favour of biofertilizer treatments to enhance the performance of seed quality as reported by El-Sirafy *et al.* (2006) [7] in wheat, Zaki *et al.* (2009) [22] in rice, Mahato *et al.* (2017) [15] in maize. Chlorpyrifos showed an adverse effect individually, as well as in combination with Vitavax and *Azotobacter* on amongst the parameters it might be due to the chlorpyrifos depressed the nitrogen metabolism, amylase, and ATPs activities, impaired respiration and caused the inhibition of normal cell division or elongation and depressed the late germination of the seedling and caused the lowest germination, seedling length, seedling dry weight, and vigor indices, Dalvi *et al.* (1972) [5] in wheat and mungbean. Using biofertilizer treatments is strongly recommended over the use of insecticides and fungicides.

Table 3: Effect of seed treatments on Speed of germination of wheat

Treatments (T)	Variety (V)					
	WH1105			WH1124		
	Old	Fresh	Mean	Old	Fresh	Mean
T_0	43.36	49.36	46.36	48.11	51.76	49.94
T_1	47.38	53.11	50.25	49.74	54.65	52.19
T_2	46.11	51.24	48.68	48.82	53.80	51.31
T_3	51.04	55.95	53.49	52.98	57.38	55.18
T_4	45.33	50.23	47.78	47.46	52.35	49.90
T_5	48.55	54.33	51.44	50.61	55.12	52.86
T_6	56.92	59.01	57.97	56.66	59.53	58.09
T_7	43.89	48.23	46.06	46.79	49.23	48.01
	V	L	T	V×L	V×T	LxT
C.D. (P=0.05)	0.570	0.570	1.139	NS	NS	NS
S.Em (±)	0.202	0.202	0.403	0.285	0.570	0.570

Table 4: Effect of seed treatments on Germination (%) of wheat

Treatments (T)	Variety (V)					
	WH1105			WH1124		
	Old	Fresh	Mean	Old	Fresh	Mean
T_0	86.00 (68.01)	92.00 (73.62)	89.00 (70.82)	87.00 (68.84)	93.33 (75.02)	90.17 (71.93)
T_1	83.33 (65.88)	86.00 (68.00)	84.67 (66.94)	84.00 (66.40)	87.33 (69.13)	85.67 (67.76)
T_2	87.00 (68.85)	92.33 (73.90)	89.67 (71.38)	88.00 (69.71)	93.67 (75.43)	90.83 (72.58)
T_3	91.33 (72.86)	96.00 (78.49)	93.67 (75.67)	92.67 (74.29)	97.00 (80.08)	94.83 (77.19)
T_4	87.33 (69.13)	93.00 (74.69)	90.17 (71.91)	88.33 (70.02)	94.00 (75.82)	91.17 (72.92)
T_5	88.00 (69.72)	94.00 (76.05)	91.00 (72.88)	88.67 (70.31)	94.67 (76.70)	91.67 (73.51)
T_6	85.67 (67.74)	91.33 (72.87)	88.50 (70.30)	86.33 (68.28)	92.67 (74.29)	89.50 (71.29)
T_7	84.00 (66.39)	87.33 (69.16)	85.67 (67.78)	84.67 (66.93)	88.33 (70.00)	86.50 (68.47)
	V	L	T	V×L	V×T	LxT
C.D. (P=0.05)	0.473	0.473	0.946	NS	NS	1.337
S.Em (±)	0.167	0.167	0.335	0.237	0.473	0.473

Table 5: Effect of seed treatments on Vigor index-I of wheat

Treatments (T)	Variety (V)					
	WH1105			WH1124		
	Old	Fresh	Mean	Old	Fresh	Mean
T_0	2202	2507	2355	2296	2581	2438
T_1	2087	2263	2175	2165	2310	2238
T_2	2286	2604	2445	2417	2700	2559
T_3	2759	3126	2942	2848	3207	3027
T_4	2220	2497	2359	2325	2566	2445
T_5	2387	2730	2559	2485	2822	2654
T_6	2367	2716	2542	2454	2810	2632
T_7	2079	2247	2163	2159	2329	2244
	V	L	T	V×L	V×T	LxT
C.D. (P=0.05)	42.152	42.152	84.303	NS	NS	NS
S.Em (±)	14.917	14.917	29.834	21.095	42.191	42.191

Table 6: Effect of seed treatments on Vigor index-II of wheat

Treatments (T)	Variety(V)					
	WH1105			WH1124		
	Old	Fresh	Mean	Old	Fresh	Mean
T_0	981	1124	1053	1049	1160	1105
T_1	918	1038	978	982	1064	1023
T_2	987	1122	1055	1042	1153	1098
T_3	1259	1401	1330	1312	1429	1371
T_4	1084	1210	1147	1111	1248	1180
T_5	1048	1182	1115	1080	1217	1149
T_6	1090	1226	1158	1121	1256	1188
T_7	916	1026	971	981	1052	1016
	V	L	T	V×L	V×T	LxT
C.D. (P=0.05)	19.068	19.068	38.137	NS	NS	NS
S.Em (±)	6.748	6.748	13.496	9.543	19.086	19.086

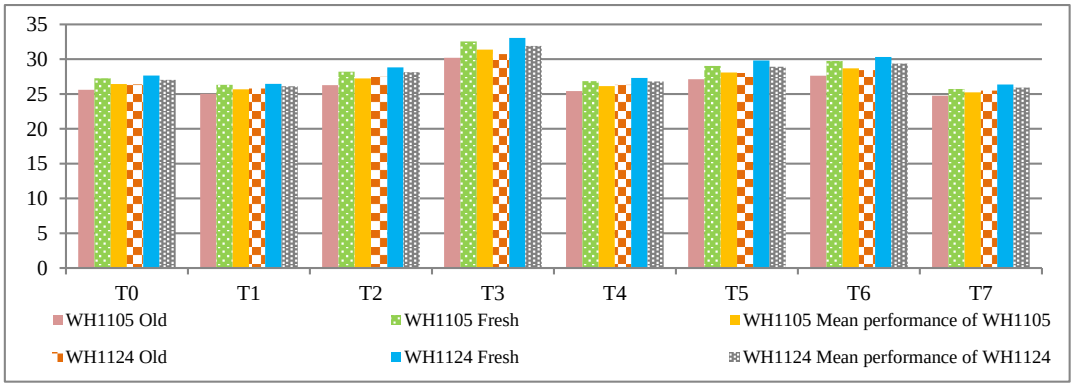

Fig 1: Effect of seed treatments on Seedling length (cm.) of wheat

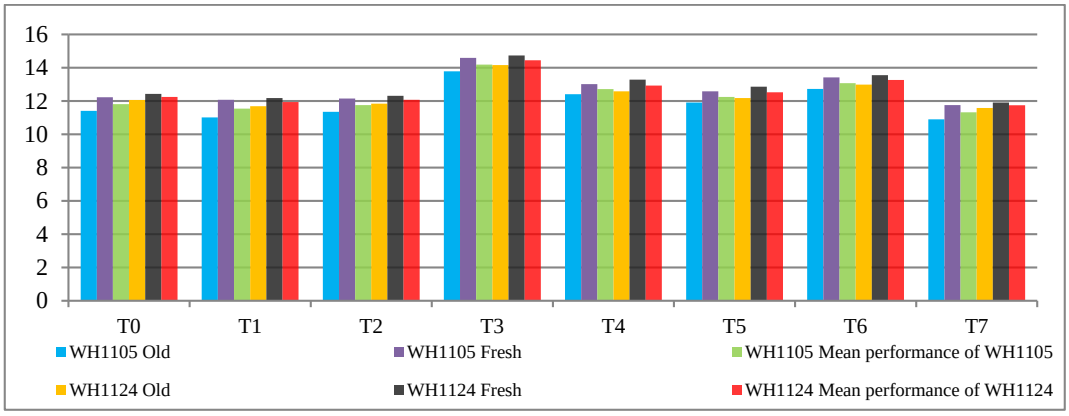

Fig 2: Effect of seed treatments on seedling dry weight of wheat

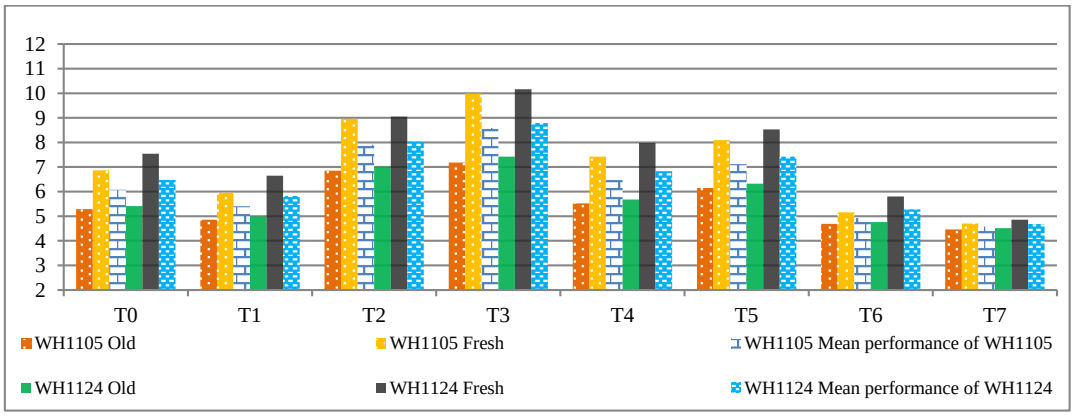

Fig 3: Effect of seed treatments on field emergence index of wheat

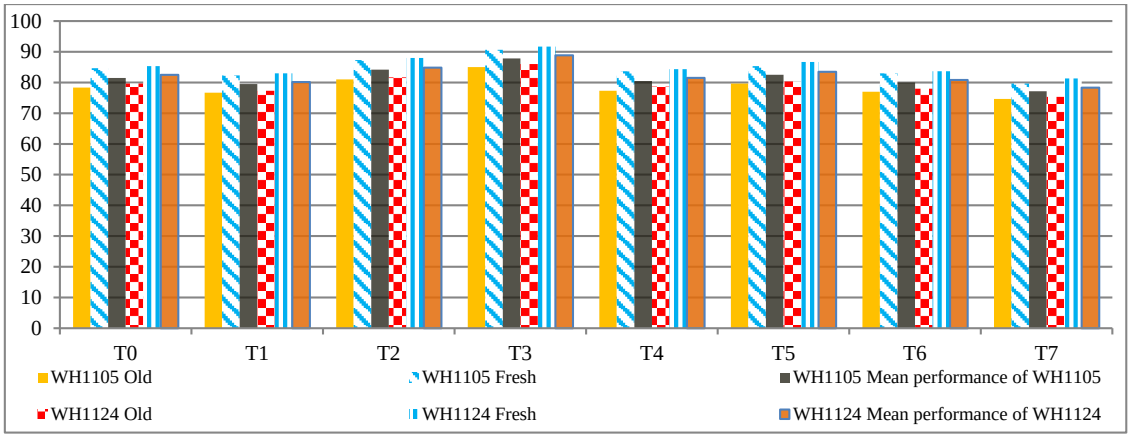

Fig 4: Effect of seed treatments on seedling establishment (%) of wheat

Conclusion

Based on the current research findings, it can be affirmed that the application of *Azotobacter* in seed treatment significantly improved various aspects of wheat seed quality. On the other hand, the use of Chlorpyrifos had a detrimental effect on the quality of wheat seeds.

References

1. Abdul-Baki AA, Anderson JD. Vigor determination in soybean seed by multiple criteria. Crop science. 1973;13(6):630-633.
2. Biswas SK, Shankar U, Kumar S, Kumar A, Kumar V, Lal K. Impact of bio-fertilizers for the management of spot blotch disease and growth and yield contributing parameters of wheat. Journal of Pure and Applied Microbiology. 2015;9(4):3025-3031.
3. DAFW. Department of Agriculture & Farmers Welfare, Govt. of India. [https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1906880]. [Visited on 30 September, 2023].
4. Das DK, Mandal M. Advanced technology of fertilizer uses for crop production. Fertilizer technology. 2015;1:19-67.
5. Dalvi RR, Singh B, Salunkhe DK. Influence of selected pesticides on germination and associated metabolic changes in wheat and mung bean seeds. Journal of agricultural and food chemistry. 1972;20(5):1000-1003.
6. Dhaliwal GS, Jindal V, Mohindru B. Crop losses due to insect pests: Global and Indian scenario. Indian Journal of entomology. 2015;77(2):165-168.
7. El-Sirafy ZM, Woodard HJ, El-Norjar EM. Contribution of biofertilizers and fertilizer nitrogen to nutrient uptake and yield of Egyptian winter wheat. Journal of plant nutrition. 2006;29(4):587-599.
8. FAO (Food and Agriculture Organization of the United Nations). FAO cereal supply and demand brief; c2023. [https://www.fao.org/worldfoodsituation/csdb/en/]. [Visited on 25 September, 2023]
9. Gupta G, Panwar J, Akhtar MS, Jha PN. Endophytic nitrogen-fixing bacteria as biofertilizer. Sustainable Agriculture Reviews. 2012;11:183-221.
10. Hamid B, Bashi Z. Potassium Solubilizing Microorganisms: An Alternative Technology to Chemical Fertilizers. Journal of Research and Development. 2019, 19.
11. ISTA. International rules for seed testing. Chapter 5: The Germination Test. ISBN 978-3-906549-53-8. International Seed Testing Association, Baserdorf, Switzerland; c2011.
12. Jenkins JA. The origin of cultivated wheat. Canadian Journal of Genetics and Cytology. 1966;8(2):220-232.
13. Kumar A, Dayal A, Rai P, Verma KR. Effect of integrated nutrient management seed quality chracters in maize (*Zea mays* L.). The Pharma Innovation Journal. 2018;7(6):367-370.
14. Maguire JD. Speed of germination-aid selection and evaluation for seedling emergence and vigor. Crop Science. 1962;2:176-177.
15. Mahato S, Neupane S. Comparative study of impact of *Azotobacter* and *Trichoderma* with other fertilizers on maize growth. Journal of Maize Research and Development. 2017;3(1):1-16.
16. Meena VS, Bahadur I, Maurya BR, Kumar A, Meena RK, Meena SK, *et al*. Potassium-solubilizing microorganism in evergreen agriculture: an overview. In Potassium solubilizing microorganisms for sustainable agriculture; c2016. p. 1-20.
17. Me Carty SC, Chauhan DS, MeCarty AD, Tripathi KM, Selvan T. Effect of *Azotobacter* and Phosphobacteria on Yield of Wheat (*Triticum aestivum*). Vegetos: An International Journal of Plant Research. 2017;30(2).
18. Panse VS, Sukhatme PV. Statistical methods for Agricultural workers (4th Edition) ICAR Publication New Delhi; c1985.
19. Singh RR, Prasad K. Effect of bio-fertilizers on growth and productivity of wheat (*Triticum aestivum*). International Journal of Farm Sciences. 2011;1(1):1-8.
20. Singh SK, Kumar S, Kashyap PL, Sendhil R, Gupta OP. Wheat. Trajectory of 75 years of Indian Agriculture after Independence. Singapore: Springer Nature Singapore; c2023. p. 137-162.
21. Tamilkodi R, Victoria J. Liquid Microbial Biofertilizers (LMF) for enhancing soil fertility: A review. International Journal of Trend in Scientific Research and Development. 2018;2(3):673-678.
22. Zaki N, Gomaa AM, Galal A, Farrag AA. The associative impact of certain diazotrophs and farmyard manure on two rice varieties grown in a newly cultivated land. Research Journal of Agriculture and Biological Sciences. 2009;5(2):185-190.