The Pharma Innovation Journal 2023; 12(9): 1088-1093

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(9): 1088-1093

www.thepharmajournal.com
Received: 14-07-2023
Accepted: 20-08-2023

SH Thube
Central Institute of Cotton Research (CICR-ICAR), Nagpur, Maharashtra, India

GK Mahapatro
Indian Agriculture Research Institute, New Delhi, India

Corresponding Author:
GK Mahapatro
Indian Agriculture Research Institute, New Delhi, India

Combinatorial efficacy and compatibility of insecticides, biofungicides and biofertilizers for seed treatment in selected major field crops

SH Thube and GK Mahapatro

Abstract
Five target crops—wheat, maize, chickpea, groundnut, and soybean—were the subject of laboratory tests to determine the compatibility of termiticides as seed treatment chemicals, specifically chlorpyriphos, imidacloprid, and fipronil, with recommended insecticide doses (@ 3, 3, 5, 5, and 4 ml/kg seed) for imidacloprid in five test-crops, as well as with bio-fertilizers (@ For the other two termiticides, namely chlorpyriphos 20 EC (@ 2, 5, 7, 6 and 4 ml/kg) and fipronil (@ 4, 5, 5, 5 and 3 ml/kg seed), the same combinations (with biofungicide and biofertilizer) were examined for test-crops including wheat, maize, chickpea, groundnut, and soybean, respectively.

The in-between paper approach (Agarwal, 1995) is used, and the results of the in vitro experiment support the following crop-specific recommendations for efficient, complementary seed treatment measures (4 g/kg for the biocontrol agent and 25 g/kg for the biofertilizer). To confirm the impact of different combination treatments on root nodulations, a supporting pot study for the pulse crop (chickpea) was conducted.

1) Imidacloprid @ 3 ml/kg + *Azotobacter* for wheat. 2) Imidacloprid @ 3 ml/kg + *Trichoderma* + *Azotobacter*. Fipronil @ 4 mg/kg with *Azotobacter*. Fipronil, *Trichoderma* + *Azotobacter*, 4 mg/kg.

Imidacloprid at 3 mg/kg plus *Azospirillum*; Imidacloprid at 3 mg/kg plus *Trichoderma* + *Azospirillum*; Fipronil at 5 mg/kg plus *Azospirillum*; Fipronil at 5 mg/kg plus *Trichoderma* + *Azospirillum*; Maize.

1) Imidacloprid @ 5 ml/kg + *Mesorhizobium* for chickpea. 2) Fipronil @ 5 ml/kg + *Mesorhizobium* 3) Fipronil @ 5 ml/kg + *Trichoderma* + *Mesorhizobium* 4) Imidacloprid @ 5 ml/kg + *Trichoderma* + *Mesorhizobium*.

Groundnut: 1) Imidacloprid @ 5 mg/kg + Bradyrhizobium 2) Imidacloprid @ 5 mg/kg + *Trichoderma* + Bradyrhizobium 3) Fipronil @ 5 mg/kg + Bradyrhizobium 4) Fipronil @ 5 mg/kg + *Trichoderma* + Bradyrhizobium.

Soybean: 1) imidacloprid at 4 mg/kg plus *R. japonicum*, 2) imidacloprid at 5 mg/kg plus *Trichoderma* + *R. japonicum* 3) fipronil @ 3 mg/kg + *R. japonicum* 4) fipronil @ 3 mg/kg + *Trichoderma* + *R. japonicum*.

The effectiveness of these suggestions may be investigated in the field, and although the insecticides employed in this study are mainly termiticides, suggestions may also be utilized to control sucking insect pests in the target crops.

Keywords: Chlorpyriphos, fipronil, imidacloprid, *Trichoderma harzianum*, *Bradyrhizobium*, *Mesorhizobium*, *Rhizobium japonicum*

Introduction
According to the Third Advance Estimate of Production of Food Grains & Oilseeds and Other Commercial Crops, 2012–13 (Directorate of Economics & Statistics, 2013) [2], the importance of major cereals (wheat and maize) and pulses (chickpea, soybean, and groundnut) is demonstrated by the fact that these five major field crops contribute approximately 115.44 million tonnes (wheat, 93.62 and maize, 21.82) and 28.06 million tonnes (IPM packages of the Government of India, Ministry of Agriculture (Directorate of Plant Protection, Quarantine & Storage 'DPPQR&S', 2001) [2] recommend chlorpyriphos 20 EC @ 4 ml/kg seed of wheat. These recommendations are insecticides only, and their compatibility with recommended bio-fertilizer (s) and bio-fungicide (*T. harzianum*) was tested in vitro for the above-mentioned target crops. seed treatment with T for maize. viae or T. It is advised to use harzianum @ 4 g/kg. This package does not include any insecticidal seed treatments (DPPQR&S, 2001) [2]. On the other hand, the Directorate of Maize Research in New Delhi suggests treating seeds with imidacloprid at a rate of 4 milliliters per kilogram to prevent termites and shoot flies

(www.dmr.res.in). Viridian T. It is advised to use harzianum @ 4 g/kg for illnesses and chlorpyriphos 20 EC @ 15–20 ml/kg of seed for termites. For various insects and diseases, seed treatment with carbosulfan 25 EC and carbendazim 20%DS was recommended. Rhizobium culture is one kind of biofertilizer described in the packaging. However, these suggestions stand alone; the use of these pesticides in conjunction is not indicated. Groundnut seeds are treated with bio-fungicide T and chlorpyriphos 20 EC @ 2.5–12.5 ml/kg seed for termite control. DPPQR&S (2001) [2] recommends using viride or *T. harzianum* @ 4 g/kg seed to control seed/seedling rot disease. On the compatibility of seed treatment insecticides, fungicides, and biofertilizers in various field crops, there is almost no literature.

Materials and Methods

The groundnut seeds (TAG-21) were purchased from the National Research Centre for Groundnut, located in Junagadh, Gujarat. On the other hand, the seeds for the test crops, namely wheat (HD-2967), maize (HQPM-1), chickpea (PUSA-1003), and soybean (DS-9712), were acquired from the Seed Unit under the Division of Genetics at the Indian Agricultural Research Institute in New Delhi. As established in the previous chapter (Research Paper-I), the seeds underwent treatment with imidacloprid 48% FS (commercially known as Gaucho® 600FS), fipronil 5SC (marketed as Regent®), and chlorpyriphos 20 EC (sold as Dursban®), following the recommended doses for each respective pesticide. Although not recommended, chlorpyriphos is applied to maize at a dosage of 5 ml/kg in a combination experiment aiming to enhance germination to a minimum of 90% (according to the International Seed Testing Association standard) when used in conjunction with biofertilizer. Both the bio-fungicide, *T. harzianum* at a concentration of 4 g per kilogram of seed, and the bio-fertilizers at a concentration of 25 g per kilogram of seed, are employed in combination with the aforementioned insecticidal treatments. The experimental design also incorporated an untreated control group.

Initially, insecticides were diluted with water to provide the requisite quantity for saturating one kilogram of seed, with the specific volume ranging between 50 and 100 ml depending on the crop type. The seeds were evenly distributed over plastic trays, followed by the application of the necessary quantity of the sole pesticide emulsion by means of sprinkling. The seeds were next subjected to a one-hour drying period under shaded conditions. Following the drying process, the seeds were subjected to treatment with a bio-fungicide, namely *Trichoderma harzianum* at a rate of 4 grams per kilogram of seeds, and a particular bio-fertilizer strain at a rate of 25 grams per kilogram of seeds, in line with the experimental crop requirements. A germination test was conducted on the treated seeds after a duration of 24 hours.

A test to assess the germination process in an artificial environment.

The seeds were subjected to the in-between paper method, as described in the previous chapter, for germination. This involved placing the seeds between two layers of germination paper in a germination chamber. The temperature range of the chamber was set at 20° to 25°C, as recommended for the specific test crop (Agarwal, 1995) [1]. The paper towel was inoculated with 100 replicates (r=3) of each treatment (t=10). In accordance with the test-crops conducted by ISTA (2007) [5], the enumeration of normal seedlings, aberrant seedlings, and ungerminated seeds took place within a period of 7-10 days subsequent to the planting process. The measurements of plumules, radicles, and the total length of the seedlings were recorded. In order to determine the vigor index, measurements were taken of the average lengths of the radicle and plumule for 10 seedlings in each replication, along with the dry weights of 10 seedlings in each replication.

A controlled laboratory experiment was conducted to investigate the root nodulation of pulse plants.

A further study focusing on pulse (chickpea) is conducted to validate the effects of combined treatments on root nodulation within the realm of pot-culture research. The identical set of eight treatments, as depicted in Table 3.4, were administered. Following the application of the required seed treatments, a total of five seedlings were cultivated in each replication within the pots. The pots were stored in a walk-in germinator room, maintained at a temperature of 200 °C and a relative humidity of 70–75%, following the guidelines outlined in the International Seed Testing Association (ISTA) standards of 2008. The seedlings received watering at intervals of six days. Final observations on root nodules were conducted 30 days following the seeding process.

The data was subjected to a factorial analysis of variance (ANOVA) using the widely accepted statistical program, OPSTAT online, which may be accessed at www.hau.ernet.in/opstat.html.

Results and Discussion

It is often necessary to provide insecticides, biofertilizers (*Azotobacter*), and biofungicides (*T. harzianum*) as seed treatments in the field. In this combinatorial method to compatibility testing, the impact of numerous combinations on the growth and development of seedlings for different crops was confirmed. Wheat (Plates 4.1 and 5.1 in Table 1)

In control the germination is 96.44 per cent.In all other combinatorial treatments T1(imidacloprid @ 3 ml/kg + *Azotobacter*), T2 (fipronil @ 4 ml/kg + *Azotobacter*),T3 (chlorpyriphos @ 2 ml/kg + *Azotobacter*), T4 (imidacloprid @ 3 ml/kg + *Trichoderma* + *Azotobacter*), T5 (fipronil @ 4 ml/kg + *Trichoderma* + *Azotobacter*), T6 (chlorpyriphos @ 2 ml/kg + *Trichoderma* + *Azotobacter*) as mentioned in Table 1;the germination range was 83.33 to 97.39%. The germination percentage for treatments T3 and T6 was less than 85%, and as a result, these combinations are not recommended by ISTA standards. Therefore, chlorpyriphos cannot be used with T or *Azotobacter*. *Azotobacter* and *H. rzianum*.

When the seeds were treated with *Azotobacter*, as expected, there was an increase in growth and development, which is very clear from values of root and shoot length and vigour indices as shown in Table 1. The total seedling length and Vigour indices I and II were 34.86 cm and 3362.58, 70.95, respectively, in the control.

Recorded seedling metrics after treatment with imidacloprid and *Azotobacter* were still better than those in the control, indicating no incompatibility issues. Instead, the increased seedling length and vigor indexes suggest a potential phytotonic effect. When T and imidacloprid were taken together. With statistical significance (P0.05%), the same pattern is maintained between Harzianum and *Azotobacter*. Thus, it was concluded that *T. harzianum* and *Azotobacter* may be administered safely with imidacloprid.

Fipronil somewhat reduced germination when combined with *Azotobacter*, although this is still above the ISTA standard. Indicators for root and shoot length and vigor are among the other characteristics that are on par or better. Based on the test conditions listed in Table 2, the combinations of fipronil, *T. harzianum*, and *Azotobacter* also demonstrated compatibility.

Maize (Plates 4.1 and 5.1 and Table 2)

Seeds of maize were treated in different combination of test insecticides, *Azospirillum* and *Trichoderma* in following way: treatments T1 (imidacloprid @ 3 ml/kg + *Azospirillum*), T2 (fipronil @ 5 ml/kg + *Azospirillum*), T3 (chlorpyriphos @ 7 ml/kg + *Azotobacter*), T4 (imidacloprid @ 3 ml/kg + *Trichoderma* + *Azospirillum*), T5 (fipronil @ 5 ml/kg + *Trichoderma* + *Azospirillum*), T6 (chlorpyriphos @ 7 ml/kg + *Trichoderma* + *Azospirillum*).

In T1 (which contains imidacloprid), there was a notable increase in germination percent as compared to control. T2 and T5 (which included fipronil) caused a modest reduction in germination, whereas T3 and T6 (which included Chlorpyriphos) revealed compatibility issues with *Trichoderma* and *Azospirillum* because it caused a considerable drop in germination when compared to the other treatments.

The treatment T4 significantly increased the length of the shoots and roots in addition to having dark green shoots (Plate 2). This may be the result of the combined effects (phytotonic/additive/synergistic impacts) of the three products (imidacloprid, *Trichoderma*, and *Azospirillum*) on the seedlings. In treatments of chlorpyriphos (T3 and T6) using a combinatorial method, reverse effects were seen (dramatic reduction in root and shoot length). This inquiry makes obvious that there is a compatibility issue with chlorpyriphos with *Azospirillum* and *Trichoderma*. Fipronil-containing treatments (T2 and T5) also showed a little compatibility issue as a slight decrease in overall seedling length was noted.

The treatments T1 and T4, which are a combination of imidacloprid, *Azospirillum*, and *T. harzianum*, resulted in a significant increase in both the vigor indices I & II (statistically significant with all other treatments at P=0.05), which suggests a potential phytotonic effect on seedlings with a higher degree of compatibility among treated products. Fipronil combination therapy (T2, T5) resulted in a small decline in vigor indicators compared to control. Treatments (with T3, T6, and chlorpyriphos) nevertheless, shown a significant decline in vigor indexes. Additionally, seedlings with a quality of light yellow color were obtained (Plate 5.2). This is explained by chlorpyriphos' low compatibility with *Azospirillum* and *Trichoderma*.

(Table 3) Chickpea

The germination of seeds in treatments containing imidacloprid T1 (imidacloprid @ 5 ml/kg + *Mesorhizobium* and T4 (imidacloprid @ 5 ml/kg, *Trichoderma* and *Mesorhizobium*) was higher than that of the control but statistically at par with the control value; as well as in treatments in which seeds were treated only with *Mesorhizobium* and showed no compatibility problem. Treatments T2 and T5 (which included fipronil) caused a little drop in germination, demonstrating a minor compatibility issue, however this may be tolerated since germination is above the ISTA criteria (>85%) decreased the amount of seed that germinated, as well as the color of the seedlings, which became light yellow, and the pace at which they grew. These effects are statistically significant when compared to the control value, and they demonstrate the considerable incompatibility of chlorpyriphos with *Mesorhizobium* and *Trichoderma*.

Combinatorial seed treatments resulted in a control seedling with a total length of 36.4 cm. In contrast, it is much higher in the treatments T7 (seed treated with simply *Mesorhizobium*; 38.5 cm), T2, and T4 (imidacloprid + *Trichoderma* + *Mesorhizobium*). The corresponding control Vigor Index-I and II values were 3510.31 and 70.95. In T1 (3885.73 and 78.20), T4 (3930.99 and 78.74), and T7 (3680.55 and 76.16), the vigor indices (I and II) significantly rose. It suggests a potential phytotonic impact. Vigor indices (both I and II) were drastically reduced in treatments T3 and T6 (which also included chlorpyriphos). Combination issues were a prominent consideration in all treatments, including chlorpyriphos, for the aforementioned assessed parameters.

Pot trial for the root nodulation test (Table 3, Fig. 5.1, and Plate 5.3)

A separate pot experiment being conducted for chickpea root nodulation. According to the findings, Rhizobium culture increased the number of root nodules in pulse seedlings that had been treated (11 vs 7.66 root nodules/seedling in control). Rhizobium and Rhizobium + *Trichoderma* treatments with chlorpyriphos had a negative impact on root nodules (T3 = 8.66; T6 = 7.33 as opposed to T7 (with biofertilizer) = 11 root nodules/seedling). Along with biofertilizer and biofungicide, the termiticidal seed treatments imidacloprid and fipronil both shown improved root nodulation. The field validation of these combinatorial therapies is therefore possible.

To guarantee symbiotic efficacy for sufficient nodulation and nitrogen fixation in pulses, seed is additionally infected with a specialized, effective N2-fixing strain of Rhizobium. According to many researchers, these fungicides and insecticides have no suppressive effects on the development characteristics of legumes when used at the approved rate of treatment (Ghosh et al. 2003; Guene et al. 2004). On the other hand, fungicides and insecticides may negatively impact the rhizobial symbiosis between legumes and other plants by preventing the applied rhizobia from surviving on the seed at sowing time. This might result in rhizobia establishing slowly in the rhizosphere, which could decrease nodulation and N2 fixation. According to recent research by Fox et al. (2007), the herbicides chyrsin, methyl parathion, DDT, bisphenol A, and pentachlorophenol decreased the symbiotic effectiveness of rhizobia in alfalfa. With this in mind, the effectiveness of fungicide, insecticide, and the Rhizobium inoculant strain was assessed in vitro in chickpea, and effects on germination, seedling lengths, and vigor indices were noted.

(Table 4 and Plates 4.1 and 5.1) Groundnut

The germination rate was 96.03 percent in the control, but it ranged from 88.07 to 96.23 percent in the other combinatorial treatments, including T1 (imidacloprid @ 5 ml/kg + Bradyrhizobium), T2 (fipronil @ 5 ml/kg + Bradyrhizobium), T3 (chlorpyriphos @ 10 ml/kg + Bradyrhizobium), T4 (imida

The effects of treatments T3 and T6 were negative because germination significantly decreased. However, the germination rate was higher than the minimum seed germination criterion of 70% set by ISTA (2007) [5]. Therefore, field validation studies using these combinations are advised. The germination percentage for T2 and T5 (containing fipronil) was comparable to control.

When seeds were treated with Bradyrhizobium, vigour indices I and II were 2577.65 and 78.13, respectively. As predicted, there was increased growth and development, which is very clear from their values of total length and vigour indices I and II as compared to respective values of 26.83, 2577.07 and 67.22 in control.

Recorded seedling parameters rose after treatment with imidacloprid (5 ml/kg) and Bradyrhizobium, indicating a better degree of compatibility. The same favorable tendency was statistically significant when imidacloprid was taken with Bradyrhizobium and *T. harzianum*. Higher seedling vigor and length indexes suggest a potential phytotonic effect. Thus, it may be concluded that imidacloprid can be administered safely with Bradyrhizobium and *T. harzianum*.

Fipronil somewhat decreased germination when combined with *Trichoderma* and Bradyrhizobium, although this is still above the ISTA standard. Indicators for root and shoot length and vigor are among the other characteristics that are on par or better. Based on the test parameters listed in Table 4, it was determined that the combination of Fipronil + T.harzianum + Bradyrhizobium was efficient and compatible.

Soybean (Plates 4.1 and 5.1, Table 5)

Germination ranged from 83.33 to 97.39 percent in all other tested combinatorial treatments, including T1 (imidacloprid @ 4 ml/kg + Rhizobium japonicum), T2 (fipronil @ 3 ml/kg + *R. japonicum*), T3, and T4 (chlorpyriphos @ 4 ml/kg + *Trichoderma* + Bradyrhizobium). However, the germination percentage was over 75%, which is the minimum seed germination criterion according to ISTA. T3 and T6 indicated negative effects and a significant fall in germination percentage were observed. However, decisions must also be based on other factors (such as vigor indices). Combinations containing chlorpyriphos decreased germination (quantitatively). A compatibility issue with R is shown by the seedlings' statistically significant lowered development rate and qualitatively light yellow coloration (Plate 5.5). *Trichoderma* and Japonica. The germination % was modestly but not significantly changed by fipronil treatments (T2 and T5) as opposed to T3 and T6.

In the control, the total seedling length was 34.87 cm. The relative vigor indices I and II were 3362.58 and 57.58. The values of total length (37.07cm) and vigor indices I and II (3540.78,75.58) as presented in Table 5 demonstrate that, as predicted, there was greater growth and development when the seeds were treated with *R. japonicum*.

when seeds were treated with R. (4 ml/kg) and imidacloprid (4 ml/kg). japonicum, the measured seedling parameters were still superior and demonstrated a greater degree of compatibility. The same beneficial trend is maintained with statistical significance when imidacloprid was used in combination with *T. harzianum* and *R. japonicum*. The increased seedling length and vigor indicators suggest a potential phytotonic effect. In order to increase development rate and dry weight accumulation, imidacloprid may be administered combined with *T. harzianum* and *R. japonicum*.

Table 1: Effect of combinatorial seed treatments on various growth parameters of wheat variety 'HD-2967'

Treatments details	Germination (%)	Root Length (cm)	Shoot Length cm)	Total length (cm)	Vigour index-I	Vigour index-II
T$_{1}$: imi + azoto	96.39a [79.68]	21.03$_{a}$ (4.7)	18.03$_{b}$ (4.27)	38.9$_{b}$ (6.27)	3875.73$_{a}$(62.08)	77.20$_{a}$ (8.8)
T$_{2}$: fipr + azoto	90.67$_{c}$ [72.24]	18.87$_{b}$ (4.47)	16.2$_{cd}$ (4.06)	35.67$_{c}$ (6.04)	3350.21$_{c}$(57.97)	68.24$_{de}$ (8.37)
T$_{3}$: chlr + azoto	83.43$_{d}$ [65.74]	15.93$_{c}$ (4.14)	13.6$_{f}$ (3.73)	29.63$_{e}$ (5.52)	25.76.3$_{d}$ (50.87)	45.16$_{g}$ (6.86)
T$_{4}$: imr + triz + azoto	95.03$_{ab}$ [77.49]	20.81$_{a}$ (4.68)	19$_{a}$ (4.38)	40.26$_{a}$ (6.40)	3952.93$_{a}$ (62.96)	77.75$_{a}$ (8.92)
T$_{5}$: fipr + trzi + azoto	92.11$_{c}$ [73.77]	19.62$_{b}$ (4.55)	15.6$_{e}$ (4.04)	35.31$_{c}$ (6.01)	3370.36$_{c}$ (58.15)	67.90 E (8.35)
T$_{6}$: chlr + triz + azoto	82.33$_{d}$ [64.88]	16$_{c}$ (4.14)	16.6$_{f}$ (3.71)	29.83$_{e}$ (5.54)	2559.66$_{d}$ (50.7)	55.39$_{f}$ (7.57)
T$_{7}$: Azotop	94.17$_{b}$ [76.45]	20.06$_{ab}$ (4.6)	13.4$_{c}$ (4.11)	36.7$_{c}$ (6.07)	3594.22$_{b}$ (59.51)	74.81$_{b}$ (8.75)
T$_{8}$: Control	95.44$_{ab}$ [78.14]	17.46$_{c}$ (4.63)	16,13$_{c}$ (4.05)	33.86$_{d}$ (5.89)	3352.58$_{c}$ (98.0)	69.95$_{c}$ (8.47)
SE(d)	1.06	0.044	0.02	0.046	0.435	0.04
CD (P=0.05)	[2.28]	(0.10)	(0.06)	(0.1)	(0.92)	(0.09)

[imi=imidaclorpid 48%FS (@ 3 ml/kg), fipr=fipronil5FS (@ 4 ml/kg); chlr=chlorpyriphos20 EC (@ 2 ml/kg), triz=*T. harzianum* (@ 4 g/kg); & azoto=*Azotobacter* (@ 25 g/kg seed)]

The figures included in square brackets [] represent values that have undergone an arcsine transformation, whereas the figures enclosed in parenthesis () represent values that have undergone a square root transformation. The figures shown in this study are the mean values obtained from three independent repetitions, with each replication consisting of 100 seeds. Figures inside the identical column, accompanied by identical lowercase letters, do not exhibit statistically significant differences (P=0.05).

Table 2: Effect of combinatorial seed treatments on various growth parameters of maize variety 'HQPM-1'

Treatments details	Germination (%)	Root length (cm)	Shoot length (cm)	Total length (cm)	Vigour Index-I	Vigour Index-II
T$_{1}$: imi + azosp	95.39a [79.68]	20.70$_{a}$ (4.75)	18.3$_{a}$ (4.51)	39.73$_{a}$ (6.45)	3956.88$_{a}$ (62.00)	77.20$_{a}$ (8.8)
T$_{2}$: fipr + azosp	90.67$_{c}$ [72.24]	18.70$_{b}$ (4.54)	16.63$_{b}$ (4.32)	37$_{c}$ (6.24)	3473.08$_{c}$ (58.03)	68.24$_{de}$ (8.37)
T$_{3}$: chlr + azosp	83.43$_{d}$ [65.74]	17.66$_{c}$ (4.19)	13.73$_{c}$ (3.97)	30.73$_{d}$ (5.71)	2669.47$_{d}$ (50.77)	45.16$_{g}$ (6.86)
T$_{4}$: imi + tri + azosp	95.03$_{ab}$ [77.49]	20.81$_{a}$ (4.77)	18.26$_{a}$ (4.50)	40.43$_{a}$ (6.50)	3968.97$_{a}$ (62.09)	77.75$_{a}$ (8.92)
T$_{5}$: fipr + triz + azosp	92.11$_{c}$ [73.77]	20.61$_{a}$ (4.74)	17$_{b}$ (4.36)	39.61$_{a}$ (6.44)	3771.38$_{b}$ (60.5)	67.90 E (8.35)
T$_{6}$: chlr + triz + azosp	82.33$_{d}$ [64.88]	14.23$_{d}$ (4.02)	13.76$_{c}$ (3.97)	28.9$_{e}$ (5.55)	2481.4$_{e}$ (48.92)	55.39$_{f}$ (7.57)
T$_{7}$: azosp	94.17$_{b}$ [76.45]	21.46$_{a}$ (4.83)	17.26$_{b}$ (4.39)	39.6$_{a}$ (6.44)	3853.91$_{ab}$ (61.17)	74.81$_{b}$ (8.75)
T$_{8}$: Control	95.44$_{ab}$ [78.14]	20.4$_{a}$ (4.72)	16.7$_{b}$ (4.33)	38.21$_{b}$ (6.73)	3772.16$_{b}$ (60.51)	69.95$_{c}$ (8.47)
SE(d)	1.07	0.074	0.036	0.045	0.5	0.04
CD (P=0.05)	[2.28]	(0.15)	(0.07)	(89.1)	(1.06)	(0.08)

[imi=imidaclorpid 48%FS (@ 3 ml/kg), fipr=fipronil5FS (@ 5 ml/kg); chlr=chlorpyriphos20 EC(@ 5 ml/kg), triz=*T. harzianum* (@ 4 g/kg); & azosp =*Azospirillum* (@ 25 g/kg seed)]

The figures included in square brackets [] represent values that have undergone an arcsine transformation, whereas the figures enclosed in parenthesis () represent values that have undergone a square root transformation. The figures shown in this study are the mean values obtained from three independent repetitions, with each replication consisting of 100 seeds. Figures inside the identical column, accompanied by identical lowercase letters, do not exhibit statistically significant differences (P=0.05).)

Table 3: Effect of combinatorial seed treatments on various growth parameters of chickpea variety 'PUSA-1003'

Treatments details	Germination (%)	Root length (cm)	Shoot length (cm)	Total length (cm)	Vigour Index-I	Vigour Index-II	*Root nodules (no./plant)
T_1: imi + rhizo	95.39a [79.68]	20.21_{abc} (4.7)	17.13_a (4.36)	38.9_{ab} (6.3)	3875.73_a (62.33)	77.20_a (8.8)	11_{ab} (3.59)
T_2: fipr + rhizo	90.67_c [72.24]	19.03_c (4.57)	14.63_{bc} (4.07)	35.67_c (6.13)	3350.58_d (57.96)	68.24_d (8.37)	10.32_b (3.36)
T_3: chlr + rhizo	84.10_d [66.28]	15.66_d (4.19)	12.33_d (3.78)	29.33_d (5.5)	2571.33_e (50.61)	54.31_e (7.49)	8.65_c (3.1)
T_4: imi + tri + rhizo	95.03_b [77.49]	20.81_{ab} (4.77)	17.76_a (4.44)	39.93_a (6.47)	3920.99_a (62.7)	77.74_a (8.92)	12_a (3.73)
T_5: fipr + triz + rhizo	92.11_c [73.77]	19.62_{bc} (4.64)	14.33_c (4.03)	34.97_c (6.07)	3339.36_d (57.87)	67.90_d (8.35)	10_b (3.45)
T_6: chrl + triz + rhi	82.33_d [64.90]	16_d (4.23)	12.5_d (3.8)	29.83_d (5.63)	2559.67_e (50.69)	53.72_e (7.46)	7.30_d (2.88)
T_7: rhizop	94.60_b [66.33]	21.47_a (4.83)	15.16_b (4.2)	37.5_b (6.28)	3670.55_b (60.66)	75.16_b (8.74)	10_b (3.45)
T_8: Control	95.44_{ab} [78.14]	19.83_{abc} (4.66)	14.26_c (4.02)	35.4_c (6.11)	3500.31_c (59.25)	69.95_c (7.66)	7.65_{cd} (2.93)
SE(d)	0.877	0.08	0.042	0.056	0.512	0.032	0.10
CD (P=0.05)	[1.8]	(0.16)	(0.08)	(0.11)	(1.1)	(0.06)	(0.0.22)

*Root nodules were observed in a separate pot culture trial (after 30 days of sowing).

[imi=imidaclorpid 48%FS (@ 5 ml/kg), fipr=fipronil5FS (@ 5 ml/kg); chlr=chlorpyriphos20 EC (@ 7 ml/kg), triz=*T. harzianum* (@ 4 g/kg); &rhizop=*Mesorhizobium* (@ 25 g/kg seed)]

The figures included in square brackets [] represent values that have undergone an arcsine transformation, whereas the figures enclosed in parenthesis () represent values that have undergone a square root transformation. The figures shown in this study are the mean values obtained from three independent repetitions, with each replication consisting of 100 seeds. Figures inside the identical column, accompanied by identical lowercase letters, do not exhibit statistically significant differences (P=0.05).

Table 4: Effect of combinatorial seed treatments on various growth parameters of groundnut variety 'TAG-24'

Treatments details	Germination (%)	Root length (cm)	Shoot length (cm)	Total length (cm)	Vigour Index-I	Vigour Index-II
T_1: imi + rhizop	95.23_a [77.78]	13.47_{abc} (3.92)	13.93_a (3.98)	28.40_{ab} (5.5)	2819.10_{ab} (53.1)	83.36_b (9.23)
T_2: fipr + rhizop	95.00_a [77.45]	13.00_{bc} (3.86)	11.47_b (3.66)	25.47_c (5.23)	2530.90_c (50.41)	76.76_c (8.87)
T_3: chlr + rhizop	87.07_c [68.77]	10.37_d (3.51)	8.13_c (3.17)	19.50_d (4.63)	1794.81_d (42.48)	55.07_f (7.54)
T_4: imi + triz + rhizop	94.50_b [77.49]	13.97_a (4.01)	14.30_a (4.03)	30.27_a (5.58)	2880.31_a (53.76)	86.22_a (9.38)
T_5: fipr + triz + rhizop	93.43_b [75.43]	13.53_{ab} (3.93)	11.40_b (3.65)	29.93_c (5.28)	2533.34_c (50.42)	73.29_d (8.67)
T_6: chlr + triz + rhizop	87.50_c [69.15]	10.77_d (3.56)	7.30_d (3.04)	19.07_d (4.58)	1765.99_d (42.14)	53.28_g (7.43)
T_7: Trhizop	95.07_a [77.54]	13.23_{abc} (3.89)	13.57_a (3.94)	27.80_c (5.28)	2756.65_b (52.6)	77.13_c (8.89)
T_8: Control	95.03_a [77.49]	13.03_{bc} (3.87)	11.80_b (3.7)	25.83_b (5.45)	2567.07_c (50.76)	66.22_e (8.25)
SE(d)	0.79	0.05	0.057	0.056	0.532	0.028
CD (P=0.05)	[1.70]	(0.11)	(0.12)	(0.12)	(1.14)	(0.06)

[imi=imidaclorpid 48%FS (@ 5 ml/kg), fipr=fipronil5FS (@ 5 ml/kg); chlr=chlorpyriphos 20 EC(@ 6 ml/kg), triz=*T. harzianum* (@ 4 g/kg); &rhizop=Bradyrhizobium (@ 25 g/kg seed)]

The figures included in square brackets [] represent values that have undergone an arcsine transformation, whereas the figures enclosed in parenthesis () represent values that have undergone a square root transformation. The figures shown in this study are the mean values obtained from three independent repetitions, with each replication consisting of 100 seeds. Figures inside the identical column, accompanied by identical lowercase letters, do not exhibit statistically significant differences (P=0.05).

Table 5: Effect of combinatorial seed treatments on various growth parameters of soybean variety 'DS 9712'

Treatments details	Germination (%)	Root Length (cm)	Shoot Length (cm)	Total length (cm)	Vigour index-I	Vigour index-II
T_1: imi + rhizop	95.39a [80.67]	20.70_a (4.75)	17.13_b (4.36)	38.57_b (6.36)	3843.18_a (62.07)	77.20_a (8.8)
T_2: fipr + rhizop	90.67_c [73.23]	18.70_{bc} (4.54)	15.3_c (4.15)	35.67_c (6.13)	3349.9_c (57.96)	60.37_d (7.8)
T_3: chlr + rhizop	83.43_d [66.73]	15.6_d (4.19)	12.7_e (3.82)	29.63_e (5.61)	2576.37_d (50.86)	45.43_f (6.88)
T_4: imi + triz + rhizop	95.03_{ab} [78.48]	20.81_a (4.77)	18.1_a (4.47)	40.27_a (6.49)	3952.93_a (62.95)	77.75_a (8.92)
T_5: fipr + triz + rhizop	92.11_c [74.76]	19.63_{ab} (4.64)	14.67_d (4.07)	35.31_c (6.1)	3370.36_c (58.14)	67.90 E (8.35)
T_6: chlr + triz + rhizop	82.33_d [65.87]	16_d (4.23)	12.5_e (3.8)	29.83_e (5.63)	2559.67_d (50.69)	55.39_f (7.57)
T_7: Trhizop	94.17_b [77.44]	19.73_{ab} (4.65)	15.7_c (4.2)	36.07_c (6.16)	3530.78_b (59.5)	74.58_b (8.74)
T_8: Control	95.44_{ab} [79.13]	17.47_c (4.72)	15.23_c (4.14)	33.87_d (5.98)	3352.58_c (58.01)	56.58_e (7.66)
SE(d)	1.07	0.07	0.03	0.048	0.437	0.028
CD (P=0.05)	[2.28]	(0.14)	(0.06)	(0.1)	(0.93)	(0.05)

[imi=imidaclorpid 48%FS (@ 4 ml/kg), fipr=fipronil5FS (@ 3 ml/kg); chlr=chlorpyriphos20 EC(@ 4 ml/kg), triz=*T. harzianum* (@ 4 g/kg); &rhizop=Rhizobium japonicum (@ 25 g/kg seed)]

The figures included in square brackets [] represent values that have undergone an arcsine transformation, whereas the figures enclosed in parenthesis () represent values that have undergone a square root transformation. The figures shown in this study are the mean values obtained from three independent repetitions, with each replication consisting of 100 seeds. Figures inside the identical column, accompanied by identical lowercase letters, do not exhibit statistically significant differences (P=0.05).

Conclusion

India has effectively decreased its use of pesticides without having a negative impact on agricultural production. This was made possible by suitable policies that promoted the use of IPM and opposed the use of pesticides. The notable government initiative in this regard is the Total Seed Treatment Campaign. However, it should be noted that the requirements in actual field circumstances could be different. Simply advising farmers to use insecticides may not meet the needs of the actual field. Combinatorial seed treatments may be necessary in situations with several pests and diseases, and this study is a true pioneering effort for the agricultural community in this area. The seed-treatment package is nevertheless made more realistic in a comprehensive manner in light of ICM (Integrated Crop Management) by the inclusion of the biofertilizers in the combination test.

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