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Integrated management of anthracnose and pod blight diseases of soybean (*Glycine max*) using fungicide, varietal resistance, and altered sowing dates

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ABSTRACT

Anthracnose disease, incited by *Colletotrichum truncatum*, is one of the major constraints in the soybean [*Glycine max* (L.) Merill] production worldwide. A field experiment was conducted during rainy (*kharif*) seasons of 2018 and 2019 at N E Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand to assess the combined effect of host resistance, altered sowing dates, and judicious use of fungicide in soybean under natural conditions. Two soybean varieties, viz. PS 1042 and PS 1092, with three different dates of sowing and six spray schedules consisted of propiconazole, *Trichoderma harzianum*, and garlic extract were tested for their integrated effect on foliar anthracnose and pod blight diseases. Both varieties were significantly different in terms of disease severity and yield. The experiment was laid out in a split-split plot of 2 × 3 × 6 factorial design with three replications. Variety PS 1042 produced significantly higher yields (22.24 and 23.00 q/ha) than PS 1092 (16.02 and 18.37 q/ha) during both the seasons. In both the varieties, early sowing (27th June) increased the likelihood of disease and decreased yield, whereas sowing at first week of July (4th July) reduced disease severity and thereby, increased yield. Among all the treatments, the combination spray schedules of propiconazole with *T. harzinaum* and with garlic extract were found most effective or comparable with two sprays of propiconazole and gave comparatively higher yield, viz. 20.47, 20.26 and 20.76 q/ha, respectively, than control (18.30 q/ha) and other treatments. It was observed that integration of moderately resistant variety (PS 1042), seed treatment with *T. harzianum* (10 g/kg seed), sowing at first week of July, one foliar application of propiconazole (0.1%) at the time of first appearance of symptoms and second spray of *T. harzianum* (1%) after 15 days of first spray, was very effective in terms of reducing disease severity and increasing yield.

Keywords: *Colletotrichum truncatum,* Garlic extract, Integrated disease management, Propiconazole, *Trichoderma harzianum,* Varietal resistance

Soybean [*Glycine max* (L.) Merill] is one of the oldest oilseed crops grown throughout the world. The plant is more considered as an oil seed crop than a pulse with its 40% protein and 20% oil. Anthracnose caused by *Colletotrichum truncatum* (Schw.) Andrus and Moore, is one of the most important foliar disease of soybean worldwide. In India, anthracnose is considered the most serious disease (Khare and Chacko 1983, Singh *et al.* 2021), occurs consistently in Uttarakhand, Himachal Pradesh, Madhya Pradesh, Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Chhattisgarh, Delhi, and nearby areas, resulting in yield losses of up to 25% (Sharma *et al.* 2014, Borah and Deb 2020). The disease causes considerable damage by reducing plant stand, seed quality, seed germination, and yield (Begum *et al.* 2008). On a global scale as well as in Indian conditions the soybean disease causes significant losses; in favourable conditions, severe anthracnose infection can result in yield losses of up to 100% (Sinclair 1989, Yang and Hartman 2016). Studies have shown that even a 1% increase in the severity of the anthracnose disease can reduce the soybean yield by 115 kg/ha (Rajput *et al.* 2022).

Conventional synthetic fungicides are the most effective and cost-efficient means for disease management, but due to the extensive uses, the pathogens can develop resistance within a few years of exposure (Zubrod *et al.* 2019, Poti *et al.* 2023), and in recent years many studies demonstrated that efficacy of fungicides is gradually decreasing against soybean anthracnose (Dias *et al.* 2016, Chen *et al.* 2018, Poti *et al.* 2020). Therefore, considerable efforts have been made to devise integrated environmentally friendly

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strategies, including use of natural compounds like plant extracts, bio control agents (El-Gamal 2007) and host resistance (Sharma *et al.* 2014, Rawat *et al.* 2021), for the control of plant diseases, thereby reducing reliance on chemical pesticides and thus saving mankind from health hazards. Similarly, alteration of sowing dates is another effective management strategy that results in a mismatch between the susceptible stage of the plant, pathogens and optimal environmental conditions, thereby reducing disease losses (Rawat *et al.* 2021). Therefore, in present investigations the integrated disease management strategies were developed by incorporating several IDM principles like avoidance (by adjusting sowing dates), exclusion (by using combination spray schedules of *T. harzianum*, garlic extract and propiconazole) and host resistance to manage the anthracnose/pod blight disease of soybean.

MATERIALS AND METHODS

The field experiment was conducted during rainy (*kharif*) seasons of 2018 and 2019 at N E Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Latitude, 29.021038; Longitude, 79.489738), Udham Singh Nagar, Uttarakhand. The experiment was laid out in a split-split plot of 2 × 3 × 6 factorial design with three replications to assess the integrated effect of two different varieties, three different dates of sowing and six spray schedules consisted of propiconazole, *T. harzianum* and garlic extract for the management of anthracnose disease of soybean. Untreated plots (no foliar sprays) were served as a control. The area of each experimental plot was 3 m × 1 m, consisted of 40 plants/plot with 45 cm row spacing. The details of treatment combinations were as follows: The main plot factors were varieties; V_1, PS 1042 and V_2, PS 1092; the sub plot factors were three different dates of sowing, D_1, 27th June; D_2, 4th July; and D_3, 11th July; and the sub-sub plot factors were treatments, T_1, Two foliar application of *Trichoderma harzianum* @1%; T_2, Two foliar application of garlic extract @10%; T_3, Two foliar application of Propiconazole 25 EC @0.1%; T_4, One foliar application of Propiconazole 25 EC @0.1% + One foliar application of *Trichoderma harzianum* @1%; T_5, One foliar application of Propiconazole 25 EC @0.1% + One foliar application of garlic extract @10%; and T_6, Control (No treatment). The seed treatment with *T. harzianum* (10 g/kg seed) was a common treatment for all except for control. The fungicides and alternative products were prepared according to the recommended dose and applied as foliar sprays, using a hand sprayer. Foliar sprays were started immediately after first symptom of disease appeared on leaves, and the interval between the first and second applications was 15 days. Fertilizers were applied in a recommended dose; 20, 40, 60 kg NPK/ha (Anonymous 2020). Weeding was done two times after sowing. The field was irrigated properly whenever dry conditions prevailed. The crop was protected from different insects-pests by spraying recommended insecticides.

The study was carried out in a naturally infested field. Ten plants per replication were randomly selected for disease assessment. Disease Severity (DS) was recorded on 0–9 standard disease rating scale (Mayee and Datar 1986) and converted to per cent disease index by using formula given by Wheeler (1969):

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Sum of individual disease rating}}{\text{Number of plant assessed} \times \text{Maximum rating}} \times 100$$

Statistical analysis: The data obtained from field experiments was analysed using split-split plot design at P<0.5. The experimental results were subjected to ANOVA (Analysis of Variance). To test for significant differences between treatments, Duncan's Multiple Range test was used by SPSS version-20. Yield for each treatment was recorded in both the years. Data of yield per plot in kg was recorded and for statistical analysis this data was converted to q/ha.

RESULTS AND DISCUSSION

Effect of varieties, different dates of sowing, and treatments on disease severity of leaf anthracnose and pod blight and yield: Anthracnose leaf and pod blight appeared to be highly severe during 2018 and 2019, owing to favourable weather conditions during both cropping seasons. Results (Table 1) revealed that both varieties were significantly different in terms of disease severity. The severity index recorded for anthracnose and pod blight disease were 18.74 and 9.40% in 2018, 13.80 and 16.99% in 2019 and 16.27 and 13.04% for pooled data in cv. PS 1042. Likewise, variety PS 1092 exhibited severity index values of 22.72 and 14.77% for diseased leaves and pods in 2018, 20.55 and 25.44% during 2019 and 21.64 and 19.48% for pooled data. It is also evident from the data that there was significant difference in grain yield among the varieties in both the years. During both seasons and for pooled data, variety PS 1042 gave the high yield (22.24, 23.00 and 22.62 q/ha, respectively) as compared to the variety PS 1092 (16.02, 18.37 and 17.20 q/ha, respectively). In order to manage anthracnose in soybean germplasm, experts found that varietal resistance is highly effective (Dias *et al.* 2019). Numerous soybean varieties with resistant to moderately resistant reactions were identified (Nagaraj *et al.* 2014, Nataraj *et al.* 2020, Bhatt *et al.* 2022), which can be very useful in disease management and can be incorporated into IDM modules.

Severity of anthracnose leaf and pod blight was also significantly influenced by date of sowing in both varieties. The results showed that the early sown crops (27th June) exhibited significantly higher disease severity on both leaves and pods (23.28 and 14.73%) than those sown late at 4th July (19.86 and 11.17%) and 11th July (19.04 and 10.36%), in 2018 (Table 1). In 2019, different sowing dates had no significant effect on the severity of leaf anthracnose, but significantly affected the severity of pod blight. The least pod blight severity was observed in plants sown on 11th July (20.76%) and highest (21.87%) on the plants sown at 27th June 2019. The pooled analysis of both years also demonstrated the maximum reduction of disease severity was exhibited by late sown plants. The interactions between soybean varieties and different sowing dates also significantly reduced disease levels. Changing the sowing date creates a mismatch between the plant's vulnerable stage, pathogens, and optimal environmental conditions, thus reducing disease losses (Rawat *et al.* 2021). In our study, we found that the late sowing of soybean is effective at mitigating the severity of foliar anthracnose and pod blight disease as compared to the early sowing. These results are in agreement with the findings of Gawade and Suryawanshi (2011) who observed that late sown soybean crop (25th July) exhibited least severity of foliage anthracnose (9.10–10.73%) as well as of pod blight (6.43–14.09%), while crop sown on 25th June (early sowing) recorded high disease intensity of 20.36–26.07% and 10.98–22.48%, respectively. Similar results were obtained by Marley and Ajayi (2003) in a study of sorghum anthracnose, which showed that early sowing of sorghum in June and July had higher foliar and panicle anthracnose incidence as compared to the late sowing on August. Other researchers have also reported that shifts in planting dates influence the development of anthracnose in the field and can serve as an alternative means of anthracnose disease management (Ngugi *et al.* 2000, Chala *et al.* 2010).

Yield was also significantly influenced by date of sowing in both the cultivars. The late sown plants at 4th and 11th July showed significantly higher yield (19.41 and 19.52 q/ha, respectively) than those sown earlier at 26th June (18.46 q/ha) during 2018. The sowing dates in 2019, were determined to be non-significant in terms of grain yield. However, the pooled analysis of two year's data revealed that the sowing of soybean at first week of July was effective to get higher grain yield (20.04 and 20.34 q/ha) than the last week of June (19.35 q/ha). Previous studies have also shown that the altered planting dates had a substantial effect on soybean yield (Rezai-Zadeh 2004, Azizi *et al.* 2005), as found in present study. The yield obtained from the late plants sown was significantly higher as compared to the early sown plants. However, more delay in sowing dates have negative effect on yield, may be due to the insufficient time available for the plant's growth or the plant does not

Table 1 Effect of varieties, sowing dates and treatments on the severity of foliar anthracnose and pod blight of soybean

Treatment	Anthracnose (PDI%)			Pod blight (PDI%)			Yield (q/ha)		
Varieties (A)	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
V_1	18.74^{b}	13.80^{b}	16.27^{b}	9.40^{b}	16.99^{b}	13.04^{b}	22.24^{a}	23.00^{a}	22.62^{a}
V_2	22.72^{a}	20.55^{a}	21.64^{a}	14.77^{a}	25.44^{a}	19.48^{a}	16.02^{b}	18.37^{b}	17.20^{b}
SEM	0.22	0.11	0.08	0.24	0.33	0.13	0.15	0.3	0.22
CD (P=0.05)	0.51	0.61	0.37	0.86	0.73	0.60	0.63	0.61	0.46
Dates (B)									
D_1	23.28^{a}	17.51^{a}	20.40^{a}	14.73^{a}	21.87^{a}	18.30^{a}	18.46^{b}	20.23^{b}	19.35^{b}
D_2	19.86^{b}	17.04^{a}	18.46^{b}	11.17^{b}	21.02^{ab}	16.10^{b}	19.41^{a}	20.66^{ab}	20.04^{a}
D_3	19.04^{c}	16.99^{a}	18.02^{b}	10.36^{b}	20.76^{b}	14.37^{c}	19.52^{a}	21.15^{a}	20.34^{a}
SEM	0.22	NS	0.17	0.38	0.31	0.26	0.28	NS	0.2
CD (P =0.05)	0.63		0.47	1.06	0.89	0.73	0.79		0.56
Treatment (C)									
T_1	23.44^{b}	21.48^{b}	22.46^{c}	12.64^{b}	22.79^{c}	17.62^{c}	19.21^{a}	20.63^{a}	19.92^{ab}
T_2	24.29^{b}	22.45^{b}	23.37^{b}	13.86^{b}	25.23^{b}	19.64^{b}	18.95^{a}	20.53^{a}	19.74^{b}
T_3	14.97^{d}	11.11^{c}	13.04^{d}	7.58^{d}	14.27^{f}	10.48^{f}	19.93^{a}	21.59^{a}	20.76^{a}
T_4	17.10^{c}	12.00^{c}	14.55^{c}	8.91^{cd}	16.04^{e}	11.65^{e}	19.52^{a}	21.40^{a}	20.47^{ab}
T_5	17.64^{c}	12.23^{c}	14.94^{c}	9.73^{c}	18.22^{d}	13.41^{d}	19.33^{a}	21.18^{a}	20.26^{ab}
T_6	26.95^{a}	23.78^{a}	25.37^{a}	19.79^{a}	30.73^{a}	24.73^{a}	17.84^{b}	18.76^{b}	18.30^{c}
SEM	0.31	0.38	0.23	0.53	0.44	0.37	0.39	0.37	0.28
CD (P =0.05)	0.89	1.07	0.66	1.48	1.25	1.04	1.11	1.05	0.79
CV	6.46	9.29	5.18	18.53	8.96	9.48	8.66	7.70	6.06
Interaction									
A × B	*	*	*	*	NS	*	NS	NS	NS
A × C	*	*	*	*	*	*	NS	NS	NS
B × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × B × C	NS	NS	NS	NS	NS	NS	NS	NS	NS

PDI, Per cent disease index; Duncan Multiple Range Test was represented in small letters. Different letters in each column indicate that difference between treatments is significant while same letters indicate no significant difference (P<0.05); *Significant at (P≤ 0.05); NS, Non-significant.

Treatment details are given under Materials and Methods.

reach its full potential (Moosavi *et al.* 2011) or the delay in sowing date may cause reductions in nodes/plant, dry matter production and seeds/pod, which is more likely due to low temperatures (Kumagai and Takahashi 2020).

In the present study, the efficacy of propiconazole, *T. harzianum*, and garlic extracts alone, as well as a combined spray schedule of propiconazole with *T. harzianum* or garlic extract, was evaluated against soybean foliar anthracnose and pod blight. The results showed that all treated plants showed significantly lower disease and higher yield as compare to the control (Table 1). During the year 2018, the two sprays of the propiconazole (0.1%) recorded least foliar anthracnose (14.97%) and pod blight (7.58%) disease severity, followed by propiconazole (0.1%) + *T. harzianum* (1%) (17.10 and 8.91% severity in leaves and pods) and propiconazole (0.1%) + garlic extract (10%), which gave 17.64 and 9.73 PDI in leaves and pods, respectively. The treatments viz. two foliar applications of *T. harzianum* (1%) formulation and two foliar applications of garlic extract (10%) were found least effective to reduce the disease severity in both leaves (23.44 and 24.29%) and pods (12.64 and 13.86%). During 2019, the treatments namely, two foliar sprays of propiconazole (0.1%), one foliar spray of propiconazole (0.1%) + one foliar spray of *T. harzianum* (1%) and one foliar spray of propiconazole (0.1%) + one foliar spray of garlic extract (10%), were found statistically equally effective against foliar anthracnose disease with 11.11, 12.00 and 12.23 PDI, respectively, while found significantly different for pod blight (14.27, 16.04 and 18.22%). Similarly, pooled analysis of two years' data revealed the lowest PDI in leaves (13.04%) and pods (10.48%) treated with two foliar sprays of propiconazole (0.1%), as well as in plants treated with spray schedule of propiconazole (0.1%) and *T. harzianum* (1%) formulation, with 14.55 and 11.65 PDI in leaves and pods, respectively. The spray schedule of Propiconazole (0.1%) with garlic extract (10%) was also found effective to reduce the disease severity. The interactions of soybean varieties and treatments were also found to significantly reduce disease severity in both foliage and pods, while interactions of varieties and sowing dates were not found to be significant. With respect to yield improvement, each treatment exhibited a significantly greater degree of efficacy when compared to the control group. Based on the pooled data of two years, it was observed that the plants subjected to the two foliar sprays of propiconazole gave higher yields (20.76 q/ha), followed by the plants treated with combination sprays of propiconazole with *T. harzianum (*20.47 q/ha) or garlic extract (20.26 q/ha). However, two foliar sprays of *T. harzianum* and two foliar sprays of garlic extract yielded minimum (19.92 and 19.74 q/ha) among all treatments but yet found superior over control (18.30 q/ha). All interactions viz. Varieties + Dates, Varieties + Treatments, Dates + Treatments and Varieties + Dates + Treatments were found to be non-significant (P> 0.05) for the soybean yield (Table 1). The efficacy of propiconazole, *T. harzianum*, and garlic extract against soybean anthracnose disease was reported by several workers (Jagtap *et al.* 2012, Chavan and Suryawanshi 2014, Ingle *et al.* 2014, Kale 2016). As in present study, the combination spray schedule of propiconazole with *T. harzinaum* and with garlic extract gave comparable results as two sprays of propiconazole. These findings corroborate those of several other researchers studying various crops. The combination spraying of propiconazole with garlic extract and *T. harzianum* has been found most effective in controlling green gram anthracnose disease in the field and gave highest benefits (Marak *et al.* 2020). Likewise, Handiso and Alemu (2017) observed that in chilli plants, the combined treatments of *Trichoderma* spp., plant extracts and Metalaxyl-M gave lowest anthracnose disease pressure (12.8%) and least infected fruits/plot (17.4%) as compared to the control group and the group treated with fungicide alone.

In the present study we have emphasised the judicial use of commercial fungicide with other management strategies and found that integration of moderately resistant variety, seed treatment with *T. harzianum* (10 g/kg seed), sowing at first week of July, one foliar application of propiconazole (0.1%) at the time of first appearance of symptoms and second spray of *T. harzianum* (1%) after 15 days of first one, was very effective in terms of reducing disease severity and increasing yield for the *tarai* region of Uttarakhand. Even these IDM practices are found effective for the susceptible variety as well.

REFERENCES

Anonymous. 2020. Project Coordinator's Report. All India Coordinated Research Project on Soybean, ICAR-IISR, Indore, Madhya Pradesh.

Azizi M, Faramarzi A, Abdi M and Ajly G. 2005. Effect of different planting dates on yield and yield components of soybean cultivars in the middle region. *Journal of Modern Agriculture Knowledge* **2**: 75–85

Begum M M, Sariah M, Puteh A B and Abidin M Z. 2008. Pathogenicity of *Colletotrichum truncatum* and its influence on soybean seed quality. *International Journal of Agriculture and Biology* **10**(4): 393–98.

Bhatt P, Singh K P and Aravind T. 2022. Screening of soybean varieties under natural epiphytotic conditions against anthracnose/pod blight [*Colletotrichum truncatum* (Schw.) Andrus and Moore]. *Indian Phytopathology* **75**(4): 1185–89.

Borah M and Deb B. 2020. A review on symptomatology, epidemiology and integrated management strategies of some economically important fungal diseases of soybean (*Glycine max*). *International Journal of Current Microbiology and Applied Sciences* **9**(11): 1247–67.

Chala A, Alemu T, Prom L K and Tronsmo A M. 2010. Effect of host genotypes and weather variables on the severity and temporal dynamics of sorghum anthracnose in Ethiopia. *Plant Pathology Journal* (Faisalabad) **9**(1): 39–46.

Chavan S S and Suryawanshi A P. 2014. *In vivo* evaluation of fungicides, botanicals and bioagents against *C. truncatum* causing anthracnose/pod blight of soybean. *The Bioscan* **9**(4): 1581–85.

Chen S, Wang Y, Schnabel G, Peng C A, Lagishetty S, Smith K, Luo ChaoXi, and Yuan HuiZhu. 2018. Inherent resistance to 14α-demethylation inhibitor fungicides in *Colletotrichum truncatum* is likely linked to CYP51A and/or CYP51B gene variants. *Phytopathology* **108**(11): 1263–75.

Dias M D, Pinheiro V F and Cafe-Filho A C. 2016. Impact of anthracnose on the yield of soybean subjected to chemical control in the north region of Brazil. *Summa Phytopathology* **42**(1): 18–23.

Dias M D, Dias-Neto J J, Santos M D M, Formento A N, Bizerra L V A S, Fonseca M E N, Boiteux L S and Cafe-Filho A C. 2019. Current status of soybean anthracnose associated with *Colletotrichum truncatum* in Brazil and Argentina. *Plants* **8**(11): 459.

El-Gamal N G, Abd-El-Kareem F, Fotouh Y O and El Mougy N S. 2007. Induction of systemic resistance in potato plants against late and early blight diseases using chemical inducers under greenhouse and field conditions. *Research Journal of Agriculture and Biological Sciences* **3**(2): 73–81.

Gawade D B and Suryawanshi A P. 2011. Response of sowing dates and cultivars against soybean anthracnose. *Progressive Agriculture* **11**(1): 28–33.

Handiso S and Alemu T. 2017. Integrated management of anthracnose [*Colletotrichum capsici* (Syd.)]: Implications to disease reactions, quality and growth parameters of three genotypes of chili. *American Scientific Research Journal for Engineering, Technology, and Sciences* **32**(1): 303–15.

Ingle Y V, Patil C U, Thakur K D and Kalyani I. 2014. Effect of fungicides and plant resistance activator on *Colletotrichum* leaf spot of soybean. *The Bioscan* **9**(3): 1187–90.

Jagtap G P, Gavate D S and Dey U. 2012. Control of *Colletotrichum truncatum* causing anthracnose/pod blight of soybean by aqueous leaf extracts, biocontrol agents and fungicides. *Agriculture* 1(2): 39–52.

Kale S L and Barhate B G. 2016. Management of anthracnose in soybean caused by *Colletotrichum truncatum*. *International Journal of Plant Protection* **9**(2): 583–88.

Khare M N and Chacko S. 1983. Factors affecting seed infection and transmission of *Colletotrichum dematium* f. sp. *truncata* in soybean. *Seed Science Technology* **11**: 853–58.

Kumagai E and Takahashi T. 2020. Soybean [*Glycine max* (L.) Merr.] yield reduction due to late sowing as a function of radiation interception and use in a cool region of northern Japan. *Agronomy* **10**(1): 66.

Marak T, Mahapatra S, Das T and Das S. 2020. Integrated application of botanicals, fungicides and bio-agents against anthracnose (*Colletotrichum truncatum*) of green gram to improve benefit cost ratio. *Archives of Phytopathology and Plant Protection* 1–16.

Marley P S and Ajayi O. 2003. Effect of sowing date on anthracnose of sorghum in the Nigerian Sudan Savanna. *Tropicultura* **21**(3): 117–21.

Mayee C D and Datar V V. 1986. Phytopathometry technical bulletin-1 (Special bulletin-3), Marathwada Agricultural University, Parbhani, pp. 34–37.

Moosavi S S, Akbar S M J M A, Khaneghah A M and Moghanlou B S. 2011. Study of effect of planting date on vegetative traits, reproductive traits and grain yield of soybean cultivars in cold region of Ardabil (Iran). *African Journal of Agricultural Research* **6**(21): 4879–83.

Nagaraj B T, Jahagirdar S and Basavaraja G T. 2014. Identification of resistant sources in glass house and field evaluation of soybean genotypes to anthracnose caused by *Colletotrichum truncatum* (Schw.) Andrus and Moore. *Bioscan* **9**: 1333–36.

Nataraj V, Maranna S, Kumawat G, Gupta S, Rajput L S, Kumar S, Sharma A N and Bhatia V S. 2020. Genetic inheritance and identification of germplasm sources for anthracnose resistance in soybean [*Glycine max* (L.) Merr.] *Genetic Resources and Crop Evolution* **67**: 1449–56.

Ngugi H K, Julian A M, King S B and Peacocke B J. 2000. Epidemiology of sorghum anthracnose (*Colletotrichum sublineolum*) and leaf blight (*Exserohilum turcicum*) in Kenya. *Plant Pathology* **49**(1): 129–40.

Poti T, Mahawan K, Cheewangkoon R, Arunothayanan H, Akimitsu K and Nalumpang S. 2020. Detection and molecular characterization of carbendazim resistant *Colletotrichum truncatum* isolates causing anthracnose of soybean in Thailand. *Journal of Phytopatholgy* **168**(5): 267–78.

Poti T, Thitla T, Imaiam N, Arunothayanan H, Doungsa-Ard C, Kongtragoul P, Nalumpang S and Akimitsu K. 2023. Isolates of *Colletotrichum truncatum* with resistance to multiple fungicides from soybean in northern Thailand. *Plant Disease* **107**(9): 2736–50

Rajput L S, Kumar S, Nataraj V, Shivakumar M, Maheshwari H S and Ghodki B S. 2022. Evaluation of novel fungicide for the management of soybean anthracnose disease and yield loss estimation. *Legume Research-An International Journal* 10.18805/LR-4783

Rawat L, Bisht T S and Naithani D C. 2021. Plant disease management in organic farming system: Strategies and challenges. *Emerging Trends in Plant Pathology,* pp. 611–42. Singh K P, Jahagirdar S and Sarma B K (Eds). Springer, Singapore.

Rezai-Zadeh A S. 2004. Review and determine the most appropriate planting date on soybean cultivars for cold regions Kermanshah. (*In) Proceedings of the 8th Congress of Agronomy and Plant Breeding,* Iran, pp. 386.

Sharma A N, Gupta G K, Verma R K, Sharma O P, Bhagat S, Amaresan N Saini, M R Chattopadhyay C, Sushil S N, Asre R and Kapoor K S. 2014. Integrated pest management for soybean, pp. 41. National Centre for Integrated Pest Management, ICAR-Indian Agricultural Research Institute, New Delhi.

Sinclair J B. 1989. Anthracnose of soybeans. *Soybean Diseases of the North Central Region*, pp. 92–95. Wyllie T D and Scott D H (Eds). APS Press, St. Paul, Minnesotta.

Singh P, Chatterjee A, Rajput L S, Rana S, Kumar S, Nataraj V, Vimal Bhatia, and Shashi Prakash. 2021. Development of an intelligent laser biospeckle system for early detection and classification of soybean seeds infected with seed-borne fungal pathogen (*Colletotrichum truncatum*). *Biosystems Engineering* **212**: 442–57.

Wheeler B E J. 1969. *An Introduction to Plant Diseases*. The English language Book Socity and Wiley and Sons Ltd.

Yang H C and Hartman G L. 2016. Anthracnose. *Compendium of Soybean Diseases and Pests*, pp. 31–34. Hartman G L, Rupe J and Sikora E J (Eds). American Phytopathological Society, St Paul, Minnesota, USA.

Zubrod J P, Bundschuh M, Arts G, Brühl C A, Imfeld G, Knabel A, Payraudeau S, Rasmussen J J, Rohr J, Scharmüller A and Smalling K. 2019. Fungicides: An overlooked pesticide class? *Environmental Science and Technology* **53**(7): 3347–65.