Plant Archives Vol. 25, Supplement 1, 2025 pp.1552-1559 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.214

ESTIMATION OF YIELD LOSS DUE TO STEM FLY, *MELANAGROMYZA SOJAE* (ZEHNTNER) IN SOYBEAN

R. Channakeshava[1]*, N.S. Vinoda[2], Rohini Sugandhi[2] and G. Somanagouda[3]
[1]Department of Entomology, AICRP on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
[2]Department of Entomology, College of Agriculture, University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
[3]Department of Agronomy, AICRP on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
*Corresponding author E-mail: channakeshavar@gmail.com
(Date of Receiving : 16-09-2024; Date of Acceptance : 08-11-2024)

ABSTRACT

The field experiment was carried out at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India during *Kharif* (June to September) 2022 to assess the yield loss in soybean due to stem fly, *Melanagromyza sojae*. The trial was planned in two factorial designs having protected and unprotected plots with a spacing of 30×10 cm^2 in a plot size of 5×3 m^2. Two well-known popular soybean varieties, namely DSb 21 and DSb 34 were sown. One group of these varieties was subjected to protective measures, while the other group remained untreated without any spray applications. The findings revealed that higher percentage of stem fly infestation and stemtunneling was recorded in the unprotected plots compared to the protected ones. Among the varieties, DSb 34 displayed tolerance to stem fly with lower infestation and tunneling compared to DSb 21 under both protected and unprotected conditions. DSb 34 is having narrow leaves and short growth duration made it less preferred by stem flies. And also, the study showed thatprotected plots had a significantly higher grain yield compared to unprotected plots. DSb 21 suffered more avoidable yield loss (41.53%) because of its less resistance nature compared toDSb 34 (30.72%). The recorded data revealed that DSb 34 is tolerant to stem fly damage but high yielding as compare to DSb 21. This indicates the importance of protection measures andvariety selection in optimizing grain yield and minimizing yield losses.
***Keywords*:** Soybean, Stem fly, Stem tunneling, Yield loss, Dharwad.

Introduction

Soybean (*Glycine max* (L.) Merrill) belongs to Fabaceae family, is an important pulse and oilseed crop grown in India. It is known as miracle golden bean of 20^{th} century which has revolutionized the agriculture as well as generated economy of many countries (Balasubramaniam, 1972). The crop is in high demand all over the world because of its high oil(20%) and rich protein (40%) contents. It contributes 25% to the global edible oil and supplies around two-thirds of the world's protein concentrate for livestock (Gupta *et al*, 2004). There is a global potential for the production and utilization of soybean and its derivatives for food, feed, industrial and pharmaceutical applications throughout the world (Abdullah *et al.*, 2000; Prodhan *et al.*, 2000). Globally, soybean cultivation covers a vast area, producing over 385 mt on 132.26 m ha with a productivity rate of 2.88 mt ha^{-1}. India, the world's fifth-largest soybean producer, cultivates soybean on 11.44 m ha producing 12.03 mt with a productivity of 1051 kg ha^{-1}. Major soybean-growing states in India include Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Gujarat (Khandwe *et al*, 2011; Khandare *et al*, 2021; Talekar 1989). Soybean cultivation in India was pest-free from the 1970s to the 1990s, allowing farmers toharvest without using insecticides. The luxuriant growth of soybean with its green, soft and tender foliage provides ample nourishment, habitat and shelter for various insects. Around sixty-five arthropods have been recorded to occurrence on soybean crop from pod development to harvesting period (Rai *et al.*, 1973; Akanksha and Gaur, 2015; Ambenagare *et al.*, 2011; Balaji *et al*, 2012). However, in the past two decades, the crop is being suffering from many insect pests. Among them, Stem fly, *Melanagromyza sojae* Zehntner (Diptera: Agromyzidae) has emerged as a major pest in the soybean cultivating regions of India (Chang and Ramasamy, 2014; Patel and Singh, 1976; Schläger *et al.*, 2015; Khush and Brar, 1991). The stem fly lays its eggs on underside of young leaves, creating pale pinprick spots. Once hatched, the maggot mines through the leaf, moves down thepetiole and enters the stem, creating upward and downward tunnels by consuming the pith andforming reddish-colored tunnel that shows the affected plant's appearance (Meena and Sharma, 2006; Babasaheb *et al.*, 2019; Shanower *et al.*, 1998). Before transitioningto the pupal stage within the stem, the maggot creates an exit hole for the adult emergence through the stem's vascular tissues, disrupting growth and diminishing crop yield (Motaphale *et al.*, 2016; Dey *et al.*, 2006).

Swathi *et al.* (2020) and Naik *et al.* (2021) reported that stem fly infestation affects soybean plants throughout their growth cycle, from seedling to maturity. Early-stage infestations, rarely exceed 30%, result in high seedling mortality, thereby reducing the overall crop stand (Kumar *et al*, 2009). During later growth stages, infestation levels may reach 70–100%, although soybean plants can tolerate high stem fly populations without apparent yield loss (Singh and Beri, 1973). Nonetheless, stem fly infestation significantly impacts growth parameters such as plant height, branch number, leaf area and dry matter accumulation, ultimately leading to yield reduction (Talekar, 1980; Taware *et al.*, 2008; Singh and Mishra, 1977). Therefore, it is imperative to understand the extent of yield loss attributed to stem fly infestation. Keeping the above information in view, the present study was carried out to estimate the yield loss due to stem fly, *M. sojae* in soybean.

Materials and Methods

Field experiment was conducted in Two Factorial design having protected and unprotected plots with a spacing of 30×10 cm^2 in a plot size of 5×3 m^2 during *Kharif* (June-September 2022) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India. Dharwad is located at 15^o 17' North latitude and 70^o 05' East longitude with an altitude of 678 m above the mean sea level (MSL). The popular soybean varieties viz., DSb 21 and DSb 34 were sown. One set of varieties were completely under protected condition and another set was under unprotected (without any spray) condition.

In protected plots, different chemical spray schedules were followed based on the incidence of stem fly. The soybean seeds were treated with standard check thiamethoxam 30 FS @10 ml kg^{-1} of seeds and shade dried for 30 min before sowing. Followed by two foliarsprays of thiamethoxam 25 WG @ 0.3 g l^{-1} at 15 days interval from 30 DAS were imposed with knapsack sprayer. Whereas, in unprotected condition, it is completely free from protection measures and exposed to stem fly infestation. Need-based spray was taken for defoliators in both protected and unprotected plots with lambda-cyhalothrin @ 0.5 ml l^{-1} of water. All the recommended package of practices was followed in establishing the plants except the insect pests control measures in unprotected plots.

The efficacy of insecticide treatment and response of soybean varieties to protection measures and their interaction effect was observed and significant difference was calculated using two factorial analyses.

Stem fly infestation (%)

Stem fly infestation is when the pest invades the crop. It doesn't cause immediate wilting but later leads to marginal drying of leaves. Incidence of stem fly were recorded from randomly selected five plants in both protected and unprotected plots at 15 days intervals right from germination till the incidence of pest.

$$\text{Stem fly infestation (\%)} = \frac{\text{Number of plants infested}}{\text{Total number of observed plants}} \times 100$$

Stem tunneling (%)

After infesting, stem fly maggots bore into the main stem from the petiole, damaging the stem's cortical region and vascular system, leads to noticeable tunneling. Observations on the stem tunneling were recorded from the five randomly selected plants in both protected and unprotected plots at 15 days intervals from 30 DAG (Days after germination)to 60 DAG. The stem of the plants was split opened vertically with the help of knife. Total length of the stem and tunnel length were measured for calculating the per cent stem tunneling.

$$\text{Stem tunneling (\%)} = \frac{\text{Length of the tunnel}}{\text{Total length of the stem}} \times 100$$

Estimation of avoidable yield loss

The seed yield of soybean plot^{-1} at harvest was recorded and expressed in q ha^{-1}. The yield loss (%) from both protected and unprotected plots were calculated by using the modified Abbott's formula (Tejkumar, 1979) given below.

$$\text{Crop loss estimation} = \frac{\text{Yield in treated plot} \\ \text{- Yield in untreated plot}}{\text{Yield in untreated plot}} \times 100$$

Results and Discussion

Stem fly infestation under protected and unprotected condition in different soybean varieties

The occurrence of stem fly initiates during the early stages of the crop and progressivelyrises until the pod formation stage. To minimize the impact of this pest during the early growth stages, it is crucial to implement effective protective measures. Consequently, a study was undertaken to compare soybean plots with and without protection during *kharif* 2022. During the course of study significant differences were observed between the protection levels as wellas between the varieties due to interaction effects (Table 1). At 15 days after germination (DAG), the stem fly infestation (%) was significantly higher in unprotected condition and lowest in protected condition. Among the varieties, stem fly infestationwas significantly highest in DSb 21 which recorded 2.47 and 5.54% under protected and unprotected conditions, respectively and lowest in DSb 34 which recorded 1.41 and 3.35% under protected and unprotected conditions, respectively. At 30 DAG, protected plots recorded significantly lowest stem fly infestation (%) compared to unprotected plots. Among varieties evaluated, DSb 21 recorded maximum infestation with 5.16 and 11.25% under protected and unprotected conditions, respectively. Whereas, DSb 34 recorded minimum infestation with 3.57 and 7.30% under protected and unprotected conditions, respectively. At 45 DAG, significantly lowest infestation was recorded under protected plots compared to unprotected plots. Under protected condition, DSb 34 (4.85%) recorded least stem fly infestation followed by DSb 21 (6.54%). Whereas, under unprotected condition, highest stem fly infestation was witnessed in DSb 21 (19.34%) followed by DSb 34 (12.52%). At 60 DAG, unprotected plots had significantly highest stem fly infestation compared to protected plots. Significantly maximum stem fly infestation was observed in DSb 21 under both protected (7.32%) and unprotected condition (25.37%) followed by DSb 34 (5.70 and 18.24% respectively).

The stem fly exhibits a preference for larger leaves, as they offer a greater surface area with more veins for oviposition compared to smaller leaves. DSb 34 with narrow leaves, has less favored by the stem fly for oviposition. Additionally, due to its short growth cycle, DSb 34manages to evade infestation by stem fly. On the contrary, DSb 21 features broad leaves and medium growth duration, making it less resistant to greater damage from stem fly infestation. The present findings are in conformity with Vishwanathan *et al.* (2016) who evaluated AVT lines against stem fly in soybean under both protected and unprotected conditions, showed DSb 28-3 and DSb 21 were moderately resistant to stem fly with least stem fly infestation. Naik *et al.* (2021) categorized DSb 28-3, DS 3102, DSb 34 as moderately resistant to stem fly infestation.

Stem tunneling under protected and unprotected condition in different soybean varieties

The soybean crop is vulnerable to stem fly damage as this pest tunnel into the stem leading to considerable yield loss. The findings revealed a higher percentage of damage in the unprotected plots compared to the protected ones with significant differences between protection levels and soybean varieties due to interaction effects (Table 2). At 30 DAG, significantly highest stem tunneling was observed under unprotected condition, while least stem tunneling was observed in protected plots. Among varieties evaluated highest stem tunneling was witnessed in DSb 21 with 3.27 and 7.48% under protected and unprotected conditions, respectively. Whereas, in DSb 34 least stem tunneling was recorded with 1.80 and 4.09% under protected and unprotected conditions, respectively. At 45 DAG, stem tunneling was increased and unprotected plots recorded highest stem tunneling whereas, protected plots recorded lowest stem tunneling in both the varieties. Under unprotected condition, the variety DSb 21 recorded maximum tunneling (16.61%) followed by DSb 34 (9.43%). Whereas under protected condition, highest tunneling (4.55%) was witnessed by DSb 21 followed by DSb 34 (3.65%). At 60 DAG, the variety DSb 21 recorded 6.12 and 22.70% stem tunneling in protected and unprotected conditions respectively. Whereas, DSb 34 recorded 4.15 and 16.85% stem tunneling in protected and unprotected conditions respectively. Significantly highest stem tunneling was found in unprotected condition while in protected plots least per cent stem tunneling was recorded. These results are supported by the findings of Rajashekhar and Krishnaveni (2022) who reported thatJS 20-34, Basara, JS 335, RVS-18 and JS 20-29 were found to be moderately resistant whereas, JS 93-05 was found to be highly susceptible against stem fly. A separate assessment of soybean cultivars was conducted at Parbhani to evaluate their performance against stem fly infestation. The results as documented by Dhore *et al.* (2023) revealed that the extent of stem tunneling due to stem fly ranged from 10.23 to 21.16%.

Response of different varieties of soybean against stem fly

The response of different varieties to stem fly infestation and stem tunneling was observed under the protected and unprotected plots are presented in Table 3. Significant difference was observed between both protection levels as well as between the varieties and interaction observed between the factors was also significant. The stem fly infestation differed statistically in different varieties irrespective of protection levels. Among the different varieties, the mean of stem fly infestation from 15 DAG to 60 DAG showed significantly higher in DSb 21 with 5.37 and 15.37% under protected and unprotected condition respectively. On the other hand, DSb 34 recorded least stem fly infestation with 3.88 and 10.35% under protected and unprotected condition respectively. The unprotected plots witnessed significantly higher infestation as compared to protected plots. Thus, accounting overall increase in stem fly infestation was 65.06 % in DSb 21 and 62.50% in DSb 34 in unprotected plots over protected ones across different varieties. The stem fly infestation (%) was differed in different levels of protection (protected and unprotected) irrespective of the varieties.

The mean of stem tunneling from 30 DAG to 60 DAG showed that stem tunneling (Table 3) varied significantly among different protection levels (protected and unprotected) regardless of the varieties. In unprotected plots, the mean percentage of tunneling was notably higher in both the varieties where DSb 21 and DSb 34 recorded 15.60 and 10.12% respectively. In contrast the protected plots recorded 4.65 and 3.20% stem tunneling in DSb 21 and DSb 34 respectively. Consequently, there were an overall 70.19 and 68.39% increase in stem tunneling in DSb 21 and DSb 34 under unprotected plots, respectively compared to the protected ones across different varieties. Present findings emphasize the importance of protective measures in mitigating the negative effects of stem fly infestation and tunneling in soybean. It also highlights that these soybean varieties exhibit variations in their susceptibility to stem fly attacks, primarily influenced by the configuration of their leaf structure for oviposition and duration of the soybean crop. Hence appropriate pest management strategies (protection) and the selection of resistant varieties are essential to ensure sustainable soybean production and minimize yield losses due to stem fly infestation.

Two factorial analysis of variance was performed to test the significance of difference among varieties, effect of insecticide treatment and their interaction for the incidence of stem fly and stem damage. The results indicate that the type of insecticide treatment used has a significant effect on the incidence of stem fly and the effectiveness of the treatment may vary across different varieties of plants. Additionally, the interaction effect highlights that the impact of protection levels is not uniform across all varieties, suggesting that different varieties responddifferently to protection measures.

Grain yield and yield loss

The study showed that protected plots had a significantly higher grain yield compared to unprotected plots (Table 4). Both the varieties, DSb 34 and DSb 21 had the highest seed yield under protected condition (2480 and 2138 kg ha^{-1} respectively) whereas, lower yield under unprotected condition (1718 and 1250 kg ha^{-1} respectively) (Fig. 1). DSb 21 suffered more avoidable yield loss (41.53%) because of its less resistance nature compared to DSb 34 (30.72%). The recorded data revealed that DSb 34 is tolerant to stem fly damage but high yielding as compare to DSb 21. This indicates the importance of protection measures and variety selection in optimizing grain yield and minimizing yield losses. These results are in line with the findings of Roopa (2018) who reported that DSb 34 exhibited the highest yield of 1665 kg ha^{-1}, while DSb 21 demonstrated the lowest yield of 1425 kg ha^{-1} both in unprotected conditions. Rajashekar and Krishnaveni (2022) revealed that JS 20-29 and RVS 2001-4-1 achieved their highest yields when protective measures were implemented. These genotypes experienced higher yield of 2374 and 2136 kg ha^{-1} respectively, when grown under unprotected conditions as compared to the protected ones.

Correlation with weather parameters

The study examined the relationship between stem fly incidence and various weather parameters, including maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, sunshine hours, rainfall and rainy days (Table 5). The stem fly population had a negative correlation with both maximum temperature (r=-0.086) and minimum temperature (r=-0.221). On the other hand, there were positive correlations between the stem fly population and maximum relative humidity (r=0.065) as well as minimum relative humidity (r=0.167). Additionally, negative correlations were observed between the stem fly population and weather parameters like rainfall (r=-0.125), rainy days (r=-0.106) and sunshine hours (r=-0.229). These correlations may be attributed to the fact that stem fly being adversely affected by higher temperatures, lower humidity and excessive rainfall, while they may thrive in cooler, more humid and less rainy conditions. The negative correlation with sunshine hours might suggest that stem flies prefer less sunny environments. The above findings were in confirmation with Swathi *et al.* (2020) who reported maximum infestation by *M. sojae* was recorded in 34^{th} standard week i.e., 27.50 and positively correlated with evening relative humidity (r=0.563) and negative relationship with minimum temperature (r=-0.65). Motaphale *et al.* (2016) observed that the incidence of stem fly on soybean plants began during the third week after sowing and persisted until the ninth standard week. Notably, their findings revealed a significant negative relationship between stem fly incidence and the minimum temperature, with a correlation coefficient of r=-0.46. Guedes *et al.* (2017) reported that the maximum infestation due to stem fly was observed (18.45% of stem tunneling) in 35^{th} SMW. However, stem fly population was positively correlated with maximum temperature (r=0.86) and negatively correlated with rainfall (r=-0.44).

Conclusion

The study revealed that, soybean variety DSb 34 was found to be tolerant genotype which recorded highest yield and lowest per cent yield loss (30.72%) against stem fly as it recorded lesser stem fly infestation of 3.88 and 10.35% under protected and unprotected conditions, respectively. The DSb 21 recorded lowest yield and highest per cent yield loss (41.53%).

Table 1: Stem fly infestation under protected and unprotected condition in different soybean varieties

Sl. No	Varieties	Stem fly infestation (%)							
		15 DAG		30 DAG		45 DAG		60 DAG	
		P	UP	P	UP	P	UP	P	UP
1	DSb 21	2.47 (9.04)	5.54 (13.61)	5.16 (13.13)	11.25 (19.58)	6.54 (14.82)	19.34 (26.09)	7.32 (15.69)	25.37 (30.24)
2	DSb 34	1.41 (6.81)	3.35 (10.55)	3.57 (10.89)	7.30 (15.67)	4.85 (12.72)	12.52 (20.72)	5.70 (13.81)	18.24 (25.28)
For comparing		S.Em.±	CD @ 5 %	S.Em.±	CD @ 5 %	S.Em.±	CD @ 5 %	S.Em.±	CD @ 5 %
Varieties		0.11	0.34	0.23	0.70	0.15	0.44	0.21	0.64
Protection level		0.10	0.29	0.21	0.62	0.13	0.39	0.19	0.58
Interaction		0.16	0.48	0.33	0.98	0.21	0.62	0.30	0.90

DAG – Days After Germination, P – Protected, UP – Unprotected
Figures in parentheses are arc sine transformed values

Table 2: Stem tunneling under protected and unprotected condition in different soybean varieties

Sl. No	Varieties	Stem tunneling (%)					
		30 DAG		45 DAG		60 DAG	
		P	UP	P	UP	P	UP
1	DSb 21	3.27 (10.41)	7.48 (15.87)	4.55 (12.31)	16.61 (24.05)	6.12 (14.32)	22.70 (28.45)
2	DSb 34	1.80 (7.71)	4.09 (11.67)	3.65 (11.01)	9.43 (17.88)	4.15 (11.75)	16.85 (24.23)
For comparing		S.Em.±	CD @ 5 %	S.Em.±	CD @ 5 %	S.Em.±	CD @ 5 %
Varieties		0.18	0.55	0.13	0.40	0.16	0.49
Protection level		0.16	0.48	0.12	0.37	0.14	0.42
Interaction		0.26	0.78	0.19	0.57	0.23	0.69

DAG – Days After Germination, P – Protected, UP – Unprotected
Figures in parentheses are arc sine transformed values

Table 3: Response of different varieties of soybean against stem fly under protected and unprotected conditions

Sl. No	Varieties	Stem fly infestation (%)		% increasestem fly infestation under unprotected over protected	Stem tunneling (%)		% increase stem tunneling under unprotected over protected
		Protected	Unprotected		Protected	Unprotected	
1	DSb 21	5.37 (13.17)	15.37 (22.39)	65.06	4.65 (12.35)	15.60 (22.79)	70.19
2	DSb 34	3.88 (11.06)	10.35 (18.06)	62.50	3.20 (10.16)	10.12 (17.93)	68.39
For comparing		S.Em.±		CD@ 5 %	S.Em.±		CD @ 5 %
Varieties		0.89		2.66	0.71		2.14
Protection level		0.84		2.52	0.63		1.89
Interaction		1.25		3.76	1.01		3.03

Figures in parentheses are arc sine transformed values

Table 4 : Assessment of yield loss due to stem fly in promising varieties of soybean

Sl. No	Varieties	Seed yield (kg ha^{-1})		Avoidable yield loss (%)
		Protected	Unprotected	
1	DSb 21	2138^{b}	1250^{b}	41.53
2	DSb 34	2480^{a}	1718^{a}	30.72
S.Em.±		0.37		
C V (%)		10.34		

Means in the columns followed by the same alphabet do not differ significantly by DMRT (*p*=0.05)

Table 5 : Correlation of weather parameters with the incidence of stem fly in soybean

Insect pest	Correlation co-efficient (r)						
	Temp. (°C)		RH (%)		Rainfall (mm)	Rainy day	Sun shine (hrs)
	Max.	Min.	Max.	Min.			
Stem fly	-0.086	-0.221	0.065	0.167	-0.125	-0.106	-0.229

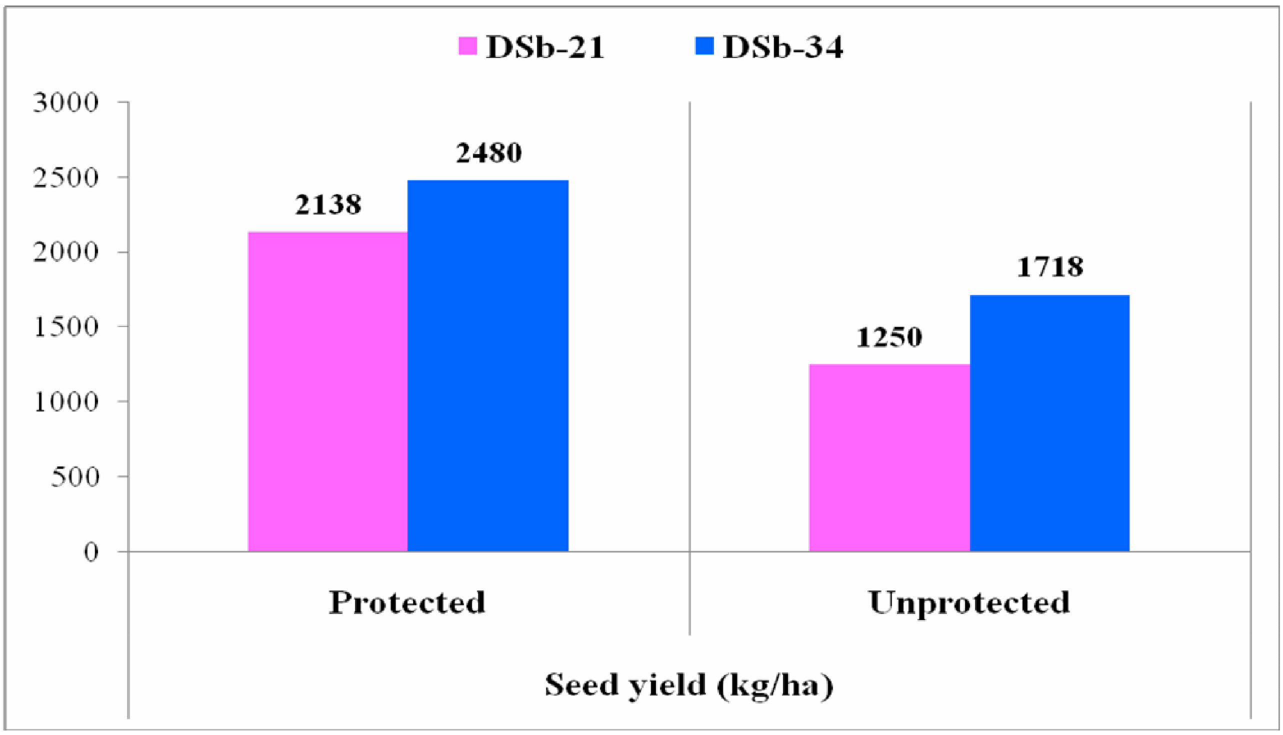

Fig. 1 : Seed yield of different soybean varieties under protected and unprotected condition

Acknowledgements

Author thanks the All India Co-ordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India for providing guidance and facilities.

Conflict of Interest

No conflict of interest.

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