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Study on Estimation of Avoidable Yield Losses Due to Pod Blight in Soybean [*Glycine max* (L.) Merr.]

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Abstract

The present study was undertaken at School of Agricultural Sciences and Rural Development (SASRD) during 2021 July to October to estimate the avoidable yield losses due to pod blight. Cultural and morphological characterization of the pathogen causing pod blight disease in the crop was concluded. White mycelia growth was initially observed in potato dextrose agar media that later turned dark brown to black. Black, oval to conical acervuli, black setae longer than condiophores and hyaline, curved conidia were observed. Percent disease incidence, percent disease severity, yield (kg ha^{-1}), and AUDPC were also recorded. Varieties as main plot factor and treatments as sub plot factor were laid out in Split plot design with three replications. Among all the combinations that were under study, moderately resistant variety (JS 97 52) with four numbers of foliar sprays recorded least disease incidence of 4.00% and least disease severity of 6.09%. Maximum (2326.67 kg ha^{-1}) and minimum (1073.33 kg ha^{-1}) yield was recorded from moderately resistant variety (JS 97 52) plot with four numbers of foliar sprays and control plot with susceptible variety, respectively. Least percent yield loss of 3.05% was observed from plots having moderately resistant variety with four foliar applications. Maximum avoidable yield loss of 37.96% was observed from susceptible plots with four foliar sprays. Maximum (256.27) and minimum (56.39) AUDPC has been observed from moderately resistant plots receiving four sprays and susceptible control plots respectively.

Keywords: Avoidable yield loss, *Colletotrichum truncatum*, pod blight, soybean

1. Introduction

Soybean [*Glycine max* (L.) Merrill], the "Miracle crop" is the world's potential and crucial seed legume (Wasule et al., 2022). The global production of soybean for the year 2019-2020 recorded 336.563 million tonnes which approximately 86% were concentrated in Brazil, the United States, and Argentina (Anonymous, 2020b). Brazil tops global soybean production 123 million metric tons and productivity 3333 kg ha^{-1} followed by America and Argentina. India is far behind and having the opportunity to improve its productivity (Anonymous, 2020a). The area and production of soybean in India was 12.17 mha and 12.72 mt during 2021–22 (Anonymous, 2022). The yield potential of recent varieties of soybean is higher (about 2100 kg ha^{-1}) as compared to average productivity (1200 kg ha^{-1}) of the country (Agarwal et al., 2013). Madhya Pradesh is the key state which grows and produces more than 50% of country's soybean. In India, nearly 98% areas under cultivation of soybean are rainfed (Dupare et al., 2014).

Soybean spread out much quicker than any other major grain or oilseed crops. The crop is extremely sensitive at different stages of crop growth starting from seed germination to physiological maturity to biotic and abiotic stresses and especially disease menace cause significant yield loss each year (Wasule et al., 2022).

Soybean is known to be affected by more than hundred plant pathogens of which very few cause tremendous losses (Bhatt et al., 2022; Masi et al., 2022). Currently, about eighteen diseases are infecting the soybean crop in India (Anonymous, 2018). Pod blight (anthracnose), caused by *Colletotrichum truncatum* (Schw.) Andrus and Moore is one of the major fungal disease and most important in terms of economic losses (Barpanda et al., 2022; Rogerio et al., 2017). Estimated yield losses attributable to anthracnose are significant (Zhu et al., 2022). In the top eight soybean producing countries (Argentina, Bolivia, Brazil, Canada, China, India, Paraguay, and the USA), grain yield losses of 25.4 mt have been reported (Wrather et al., 2010). Shift in sowing date due to delayed onset of monsoon and the attack of pod blight pathogen at later stage of crop growth reduces the quality of harvested soybean seeds in recent years (Wasule et al., 2022). This disease is especially prominent in the tropics having warm and humid climate. The disease reduces the production of the crop by 50%. The symptoms of anthracnose appear at early reproductive stages on stems, pods and petioles as irregularly shaped brown spots, but pod blight phase is the most damaging. Reddish brown spots appear on pods and later turn black (Barpanda et al., 2022; Yang et al., 2015). On leaves, necrotic laminar veins can also be observed in premature defoliation. Symptoms may evolve into premature germination of grains, pod rot, and immature opening of pods with shriveled and moldy seeds (Boufleur et al., 2021; Dias et al., 2019; Hartman et al., 2016; Mahmodi et al., 2013; Nataraj et al., 2020; Tian et al., 2017). The disease cause considerable damage by reducing the plant stand, seed quality, seed germination and yield and affected plants are significantly shorter with fewer pods and seeds with reduced seed weight (Barpanda et al., 2022). In terms of cultural and morphological characteristics, the mycelium color varies from grey, whitish grey, creamy white to white having falcate/curved, hyaline, uninucleate conidia with acute ends and acervuli with abundant setae (Ansari, 2017). The disease is a common recurrence in India. Concerning the increasing demand of the crop and the constraints in the successful cultivation of the crop, the present investigation on estimation of avoidable yield losses due to pod blight was undertaken.

2. Materials and Methods

The experiment was conducted in *Kharif* (JulyOctober, 2021) at AICRP–Soybean farm, SASRD, Medziphema, Nagaland, India.

2.1. Isolation and identification of the pathogen

Infected soybean plants were collected, isolated and identified based on its cultural and morphological characteristics.

2.2. Characteristics of the pathogen

Growth characteristics were observed in solid potato dextrose agar (PDA) medium. Morphological characters such as setae, conidia *etc*. of the isolate were also observed.

2.3. Experiment conducted under field conditions

The experiment was laid out in Split plot design with twelve treatment combinations and each replicated thrice. Plot size was 2.25× 5 m^2 and was located at 25.7566 °N and 93.8681 °E longitudes at 310 m above sea level.Two varieties *viz*., JS 335 and JS 97 52 were used as main plot factor and six treatments as sub plot factors for carrying out the experiment. Seed treatment with Thiophanate methyl 70 WP (Topsin-M) @ 2 ml kg^{-1} was done before sowing. Twenty plants were randomly selected from each plot and labeled for scoring the disease intensity and calculating percent disease incidence. The selected plants were graded using 0–9 disease rating scale (Mayee and Datar, 1986) (Table 1).

The percent disease intensity (PDI) and percent disease incidence was worked out applying formulae:-

PDI={(Sum of individual rating/No. of leaves examined)×(100/maximum disease rating)} ……………………(1)

Percent disease incidence=(No. of infected plants in sample population/Total no. of plants in sample population)×100 ....(2)

Table 1: Disease rating scale

Scale	Description
0	No lesions/spots
1	1% leaf area covered with lesions/spots
3	1.1–10% leaf area covered with lesions/spots, no spots on stem
5	10.1–25% of the leaf area covered, no defoliation; little damage
7	25.1–50% leaf area covered; some leaves drop; death of a few plants; damage conspicuous
9	More than 50% area covered, lesions/spot very common on all plants, defoliation common; death of plants common; damage more than 50%

At harvest, seed yield was recorded and data was computed on hectare basis. Further, avoidable yield loss, yield loss and AUDPC were also calculated by using the formulae;

Avoidable yield loss=(YP-YU)/YP×100……………………………(3)

where, YP=Yield under protected condition

YU=Yield under unprotected condition

Yield loss=(EY-OY)/EY×100………………………………………(4)

where, EY=Expected yield

OY=Observed yield

The area under disease progress curve (AUDPC) was computed from the PDI data recorded from each date of assessment as described by (Jeger, 2004).

$AUDPC=\sum_{i=1}^{n-1}[(y_i+y_{i+1})\div 2](t_{i+1}-t_i)$ ……………………………………………(5)

where, =Percentage severity at the i^{th}observation,

t_i=Time (days), and

n=Total number of observations

The data was statistically analyzed using suitable transformation.

The treatments details are as follows:

Table 2: Treatment details

M_1T_1	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+one foliar spray of Tebuconazole @ 2.5 ml l^{-1} at 30 DAS
M_1T_2	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+two foliar sprays of Tebuconazole @ 2.5 ml l^{-1} at 30 and 45 DAS
M_1T_3	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+three foliar sprays of Tebuconazole@ 2.5 ml l^{-1} at 30, 45 and 60 DAS
M_1T_4	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+four foliar sprays of Tebuconazole@ 2.5 ml l^{-1} at 30, 45, 60 and 75 DAS

Table 2: Continue...

M_1T_5	: Seed treatment with Thiophanate methyl @ 2ml kg^{-1}+water spray at 30, 45, 60 and 75 DAS
M_1T_6	: Control
M_2T_1	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+one foliar spray of Tebuconazole @ 2.5 ml l^{-1} at 30 DAS
M_2T_2	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+two foliar sprays of Tebuconazole@ 2.5 ml l^{-1} at 30 and 45 DAS
M_2T_3	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+three foliar sprays of Tebuconazole@ 2.5 ml l^{-1} at 30, 45 and 60 DAS
M_2T_4	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+four foliar sprays of Tebuconazole@ 2.5 ml l^{-1} at 30, 45, 60 and 75 DAS
M_2T_5	: Seed treatment with Thiophanate methyl @ 2 ml kg^{-1}+water spray at 30, 45, 60 and 75 DAS
M_2T_6	: Control

3. Results and Discussion

3.1. *Identification*

The pathogen responsible for causing pod blight of soybean was identified as *Colletotrichum truncatum* based on their morphological characteristics.

3.2. *Characteristics of the pathogen*

Mycelial growth of the pathogen in PDA medium was initially white with smooth margins which later turned brown, septate, branched with thick mycelium and the colonies turned dark brown to black. The acervuli were black, oval to conical that measured 185.6262.9 µm. Setae were black in color and were longer than conidiophores, hair like, broader at base and tapering at apex and measured 95.5–120.7 µm × 4.6–7.6 µm. Conidia were curved, hyaline, single celled, smooth walled and measured 20.023.3 µm (Figure 1).

Please provide figure 1

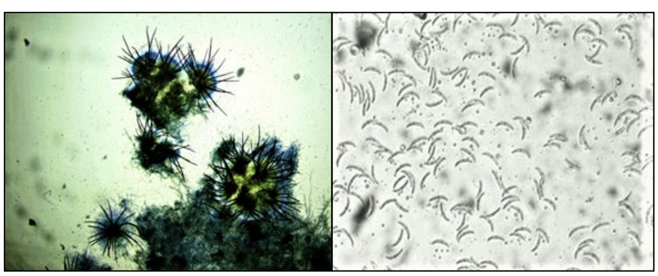

Figure 1: Acervuli, setae and conidia of the pathogen, *Colletotrichum truncatum*

The findings are in agreement with the findings reported by Akhtar et al. (2008) observed elongated, rounded acervuli approximately 350 µm in diameter, abundant setae that were swollen at the base and slightly tapered towards the polar acute apex, conidia were falcate, one-celled, hyaline and uninucleate and measured 16–30 (18–23)×2.5–4 (3.5–4) µm in size. Masoodi et al. (2013) observed cottony to fluffy, mostly suppressed with regular to irregular margins with white to grey colour of the colonies. Average conidial size varied from 2.23–33.6 µm and setae size varied from 4.48–177.21 µm. Anggrahini et al. (2020) observed that the pathogen produced grey colony on PDA medium. Conidia were falcate, aseptate and uninucleate. Setae were pointed, elongate, slightly curved, aseptate and the length ranged 50.56–104.78 µm and width ranged 20.76–25.47 µm. Yadav et al. (2021) identified anthracnose pathogen in chilli by observing upper dark gray and reverse dark brown mycelia, cottony growth on PDA medium. Conidia were hyaline, aseptate, sickle shaped measuring 23.8×3.6 µm^2. Shi et al. (2022) observed whitish-brown fungal colony surfaces initially which thereafter became gray to pale gray with ash-black color on the reverse sides, acervuli that were 124165 mm in diameter, setae linear, dartk brown to black, conidia crescent-shaped, hyaline, slightly curved with parallel walls while reporting black stem disease on sword beans.

3.3. *Percent disease incidence*

The selected plants were graded using the disease rating scale as shown in Table 1. Results obtained revealed that all the treatments under study as described in Table 2 significantly reduced disease incidence over unsprayed control.From the data (Table 3), it is evident that theleast disease incidence was found in treatments viz., four foliar sprays (JS 97 52) and three foliar sprays (JS 97 52) and they were found at par with each other with disease incidence of 4.00 and 4.16% respectively and were significantly superior over other treatments.This was followed by four foliar sprays (JS 335), two foliar sprays (JS 97 52) andthree foliar sprays (JS 335) which recorded 5.66, 6.50, 6.83% disease incidence respectively and they were significantly at par with each other. Whereas, the other treatments like two foliar sprays (JS 335) and one foliar spray (JS 97 52) were at par with each other with disease incidence of 9.33 and 10.41% respectively. This was followed by water spray (JS 97 52) and one foliar spray (JS 335) that were statistically at par with each other with 13.25 and 14.58% disease incidence respectively. Water spray in JS 335 however, recorded percent disease incidence of 22.50%. All the treatments were superior to untreated control with highest disease incidence of 20.08 and 32.25% from JS 97 52 and JS 335 respectively.

The findings are in close conformity with Chacharkar et al. (2010) who reported maximum disease incidence of 26.39% and 10.79% on leaves and branches of *Piper betle* respectively due to *Colletotrichum* blight during August to December 2007. Kumar et al. (2010) found up to 20–25% disease incidence while observing anthracnose disease on leaves of egg plant during a field survey of South Andaman, India. Rana et al. (2020) reported minimum disease intensity of 35.78% and 31.97% from Trifloxystrobin Penflufen sprayed plots for two consecutive years followed by Trifloxystrobin (41.60% and 38.6%) compared to 95.03% and 90.44% in check at 75 DAS.

Table 3: Yield loss assessment due to pod blight of soybean caused by Colletotrichumtruncatum

M × T Interaction	Disease incidence (%)	Disease Index (%)	AUDPC	Yield (kg ha^{-1})	Yield loss (%)	Avoidable yield loss (%)
M_1T_1	14.58 (21.37)*	18.63 (23.36)	165.40	1282.33	28.76	16.30
M_1T_2	9.33 (16.73)	9.85 (16.33)	84.97	1415.33	21.37	24.16
M_1T_3	6.83 (14.36)	7.29 (14.90)	70.79	1560.00	13.33	31.20
M_1T_4	5.66 (12.94)	6.38 (13.68)	61.01	1730.00	3.89	37.96
M_1T_5	22.50 (26.92)	21.41 (25.73)	184.81	1176.67	34.63	8.78
M_1T_6	32.25 (33.22)	29.36 (31.13)	256.27	1073.33	40.37	-
M_2T_1	10.41 (17.86)	14.39 (20.38)	125.11	1768.33	26.31	11.33
M_2T_2	6.50 (13.95)	9.81 (16.88)	89.78	1824.00	24.00	14.04
M_2T_3	4.16 (10.78)	6.91 (14.66)	62.09	2116.67	11.81	25.92
M_2T_4	4.00 (10.71)	6.09 (13.44)	56.39	2326.67	3.05	32.60
M_2T_5	13.25 (19.48)	17.56 (22.63)	151.13	1586.33	33.90	1.16
M_2T_6	20.08 (24.94)	21.72 (25.25)	185.45	1568.00	34.67	-
SEm±	1.22	1.08	-	32.03	0.70	-
CD (p=0.05)	3.57	3.15	-	93.50	2.05	-

*Figures in parenthesis are angular transformed values

Singh et al. (2022) reported two sprays of Carbendazim in mungbean at 15 days interval gave maximum reduction of 51.12% in disease incidence of anthracnose.

3.4. Percent disease index (PDI)

Data as presented in Table 3 revealed that all the treatment combinationssignificantly reduced the disease intensity as compared to control. Among them, four foliar sprays (JS 97 52), four foliar sprays (JS 335), three foliar sprays (JS 97 52)and three foliar sprays (JS 335) were found significantly superior over the rest of the treatments and were par at each other showing minimum disease intensity of 6.09, 6.38, 6.91 and 7.29% respectively. This was followed by two foliar sprays (JS 97 52) and two foliar sprays (JS 335) that were found significantly at par with each other with disease severity of 9.81 and 9.85 respectively followed by one foliar spray (JS 97 52) with disease severity of 14.39%. Whereas others *viz*., water spray (JS 97 52) and one foliar spray (JS 335) were found at par with each other with disease intensity of 17.56 and 18.63% respectively. Treatment with water in susceptible plots was found mediocre with a disease intensity of 21.41%.

The present readings are in accordance with Subedi et al. (2015) who reported lower percent disease index of 46.25% in plots treated with SAAF @ 2.5 g l^{-1} of water as against control with 73.57% severity. Chaudhari and Gohel, (2016) recorded minimum disease intensity (8.43%) from plots sprayed with Trifloxystrobin (25%)+Tebuconazole (50%) while carrying out experiments with different fungicides. Anand et al. (2020) reported minimum disease intensity of 18.00% from plots treated with Hexaconazole @ 0.05% followed by Trifloxystrobin @ 0.10% with 23.10% as compared to control with an intensity of 90.90% in red chilli. Chatak and Banyal, (2020) revealed that Carbendazim 50 WP @ 0.1% gave least disease severity (11.50%) as against untreated control with 52.25%. Singh et al. (2022) reported maximum reduction (64.56%) in disease severity with two sprays of Carbendazim at 15 days interval while conducting field experiments with fungicides and genotypes in mungbean.

3.5. Yield (kg ha^{-1})

Regarding seed yield, the treatment combinations were significant. Highest yield (2326.67 kg ha^{-1}) was obtained from moderately resistant plot with four spraysand was found significantly superior to other treatments. Next best treatment was with three foliar sprays in moderately resistant plot (2116.67 kg ha^{-1}) followed by two sprays in moderately resistant plot (1824.00 kg ha^{-1}) which was found at par with moderately resistant plot receivingone spray (1768.33 kg ha^{-1}) and susceptible plot receiving four sprays (1730 kg ha^{-1}). This was followed by treatments with water spray in moderately resistant plot (1586.33 kg ha^{-1}), control plot with moderately resistant variety (1568 kg ha^{-1}), three sprays (1560 kg ha^{-1}), and two sprays (1415.33 kg ha^{-1}) in susceptible plots respectively, all ofwhich were statistically at par with each other. Other treatments *viz*., one foliar spray (1282.33 kg ha^{-1}) andwater spray (1176.67 kg ha^{-1}) in plots with susceptible variety were found at par with each other followed by susceptible control plots (1073.33 kg ha^{-1}) with the lowest seed yield.

The findings are in harmony with Chaudhari and Gohel, (2016) who recorded highest yield of 856 kg ha^{-1} from plots sprayed with Trifloxystrobin (25%)+Tebuconazole (50%). Anand et al. (2020) found maximum fruit yield of red chilli from plots treated with Hexaconazole @ 0.05% with 225.50 q ha^{-1} as compared to control that yielded 122.10 q ha^{-1} of fruits. Rana et al. (2020) recorded highest green fodder yield from Trifloxystrobin Penflufen being 306.70 qha^{-1} and 370.00 q ha^{-1} followed by Trifloxystrobin i.e., 298.30 q ha^{-1} and 369.17 q ha^{-1} for two consecutive crop seasons respectively. Rajput et al. 2022 observed maximum yield of 17.24 q ha^{-1} over the control (13.18 q ha^{-1}) after foliar application of Picoxystrobin 22.52% w/w SC @ 0.08%. Singh et al. (2022) recorded significant enhancement in grain yield (53.39%) of mungbean with two sprays of Carbendazim at 15 days interval.

3.6. Avoidable yield loss (%)

In the present investigation, it is evident from the data presented in Table 3 that with the increase in number of sprayings there was an increase in avoidable yield loss over untreated control. Maximum avoidable yield loss was recorded fromplots having susceptible variety with four numbers of foliar sprays (37.96%). This was followed by moderately resistant plot receiving four sprays (32.60%) and three sprays in susceptible plot (31.20%) and was found statistically at par with each other. Treatments *viz*., three sprays in moderately resistant plot (25.92%) and two sprays in susceptible plot (24.16%) were found at par with each other followed by one spray in susceptible plots (16.30%), two sprays in moderately resistant plots (14.04%), one spray in moderately resistant plots (11.33%) and water spray in susceptible plot (8.78%). However, the least avoidable yield loss was observed from moderately resistant plots that received water spray (1.16%).

The findings are in support with the findings of earlier workers *viz*., Marak et al. (2018) observed maximum and minimum avoidable yield loss of 50.63% and 20.73% in five sprayed plots and single plots respectively. Maximum avoidable yield loss of 23.55% was recorded by Rajput et al. (2022) from plots receiving foliar application of Picoxystrobin 22.52% w/w SC @ 0.08%.

3.7. Yield loss (%)

The loss in yield varied with the number of sprayings. Maximum loss was observed in untreated control and gradually decreased with the increase in the number of sprayings. Minimum yield loss of 3.05 and 3.89% was recorded from moderately resistant plots with four spraysand susceptible plots with four sprays,respectively and were at par with each other. Other treatments *viz*., three foliar sprays in moderately resistant plots and susceptible plotswere found significantly at par with each other with yield loss of 11.81 and 13.33% respectively.This was followed by two sprays in susceptible plots (21.37%), two sprays in moderately resistant plots (24.00%), one spray in moderately resistant plots (26.31%), and one spray in susceptible plots (28.76%). Treatment with water spray in moderately resistant plotwas found to be significantly at par with susceptible plots with water spray and moderately resistant control plots with yield loss of 33.90, 34.63 and 34.67% respectively. The highest yield loss to the tune of 40.37% was recorded from control susceptible plots.

Findings by Mohammed et al. (2014) reported that the yield loss was highly reduced by Mancolaxyl (22.8%) and Mancozeb (27.30%) with maximum yield loss obtained from untreated control (69.70%) in common bean. Acharya et al. (2019) reported disease onset to be most predictive of yield losses (P=0.047, r=0.71) with earlier disease onset resulting in greater yield losses. Javaid et al. (2022) recorded highest yield loss (68.42%) and lowest yield loss of 10.95% in population where the disease started at first trifoliate stage and at pod filling stage respectively.

3.8. Area under disease progress curve (AUDPC)

The data on AUDPC showed significant differences among the treatment combinations over check. However, minimum AUDPC was calibrated from moderately resistant plots receiving four sprays (56.39) followed by four sprays in susceptible plots (61.01) which was statistically at par with three foliar sprays in moderately resistant plots (62.09) followed by susceptible plots receiving three (70.79) and two sprays (84.97) respectively,two sprays (89.78) and one spray (125.11) in moderately resistant plots, respectively and water spray in moderately resistant plots (151.13) and one spray in susceptible plots (165.40). Treatments with water spray in susceptible plots (184.81) and control moderately resistant plots (185.45) were found at par with each otherwith the highest AUDPC recorded from susceptible control plots with 256.27.

The findings are in close conformity with Mohammed et al. (2014) revealed highly significant ($p<0.01$) positive correlations between percent severity index and AUDPC and computed maximum AUDPC (3197.50) from untreated control and minimum value (835.80) from plots treated with Folpan spray. Marak et al. (2018) recorded least AUDPC value of 398.48 from plots receiving five numbers of foliar sprayings. Rana et al. (2020) recorded a minimum AUDPC of 417.400 and 361.450 from Trifloxystrobin Penflufen treated plots followed by Trifloxystrobin sprayed plots with 434.750 and 448.075 for two consecutive crop seasons respectively. Rajput et al. (2022) observed minimum AUDPC (2685.95) with the application of Hexaconazole 5% EC @ 0.1% as compared to untreated control with maximum AUDPC of 3816.20.

4. Conclusion

The observations on yield loss estimation revealed comparatively lower disease incidence and severity with increase in seed yield along withmaximum reduction of yield loss in plots having moderately resistant variety, JS 97 52 and receiving four foliar sprays of Tebuconazole. The conidia of *Colletotrichum truncatum* spread through water or air and produces symptom containing dark black water-soaked lesions with the development of concentric ring of acervuli. However, the research work needs further investigation for successful incorporation at wider field levels.

5. Further Research

Authors may suggest further future course of action/research.

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