

## Original Research Article

### **Zinc Induced Resistant against yellow stem borer (*Scirpophaga incertulas*, Walker) in Rice**

#### **ABSTRACT**

To confirm the zinc induced resistant against yellow stem borer, a field experiments were conducted during *kharif* 2022 and 2023 at N. M. College of Agriculture, Navsari Agricultural University, Navsari Gujarat (India). Overall performance of the zinc treatments over two *kharif* seasons highlighting efficacy of zinc treatments in keeping the YSB damage in control both at vegetative and heading (reproductive) stages of the rice crop confirmed the superiority of treatment T<sub>2</sub> (ZnSO<sub>4</sub> @ 50 g/ha), T<sub>4</sub> (Zn- EDTA @ 25 kg/ha) and T<sub>8</sub> (foliar application of Biosynthesis Zinc nanoparticle @ 100 ppm). At vegetative stage, treatments T<sub>2</sub>, T<sub>4</sub> and T<sub>8</sub> recorded numerically the lowest mean borer damage of 6.45, 7.60 and 8.60 per cent DH attributing in 55.61, 47.69 and 40.81 per cent decline in borer damage over control, respectively. While, at the heading stage, similar treatments T<sub>2</sub>, T<sub>4</sub> and T<sub>8</sub> recorded numerically the lowest mean borer damage of 7.01, 8.28 and 9.69 per cent DH attributing in 62.63, 55.86 and 48.35 per cent decline in borer damage over control, respectively. YSB damage was significantly and negatively correlated at vegetative ( $r = -0.64^{**}$ ) and heading stage ( $r = -0.67^{**}$ ) with zinc content.

**Key words:** Zinc induced resistance, Rice, Yellow stem borer, Zinc sources

#### **INTRODUCTION**

Rice (*Oryza sativa*L.) belongs to the family Gramineae. Rice is India's prominent crop and is the premier staple food for 65 percent India's population and contributes 20-25 percent of the agricultural GDP (Singh *et al*, 2001). India is the first in terms of area (43.79 mha) and second in production (168.50 million tonnes) of rice, next only to China. with an average productivity of 2494 to 3850 kg/ha below the average world average productivity of 4600 kg/ha (Annual Report, DAC, 2020-21). In India, rice is grown in almost all the states among them, west Bengal and Uttar Pradesh have the highest rice production. Among the states, Gujarat ranked 16th with respect to rice production, contributing only 1.7% to country's total rice production in 2014 (Ministry of Agriculture and Farmer's Welfare, 2016). In Gujarat, rice is grown in an area of 0.86 million hectares covering the South and Middle Gujarat with a production of 2.84 million tonnes and productivity of 3.31 t/ha in the year 2017-18 (Pathak *et al.*, 2020). The variations in climatic zones among these areas seem to have direct impact on production and productivity of rice in the state, which are also affected by different types of stress.

Biotic stress is a major contributor towards low crop productivity and financial loss to the farmers attributing to 27.9% by insect pests (Mondal *et al.*, 2017). Nearly 300 species of insect pests are attacking rice crop at various crop growth stages and among them only 23 species cause notable damage (Pasalu and Katti, 2006). Amongst the major pests, the rice stem borer complex is the most abundant borer complex supposedly cause the major part of destruction in rice crop throughout the world (Shu *et al.*, 2000) leading to an average loss of 30% in yield (Krishnanaih and Varma, 2013). This rice borer complex comprises of yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) is the most destructive pest that attacks rice plant from seedling to maturity in almost all ecosystem in both *kharif* and rabi seasons (Nalla *et al.*, 2023) causing a yield loss of about 10-60 per cent throughout the Indian sub-continent.

Farmers are more accepting of insecticidal applications for pest management due to their fast and efficient management of insect pests but excessive and irrational dependency on chemical control of insect pests has led to secondary pest outbreak, development of pesticide resistance, resurgence, environmental pollution and harmful residue in feed, directly or indirectly affecting our health. In this context, host plant resistance (HPR) in rice is a useful and alternate strategy that can be applied to control insect pests and minimize the yield losses, keep agricultural system eco-friendly and ensuring long-term soil and environmental sustenance (Kim *et al.*, 1998). Induced resistance through chemical elicitor such as fertilizers having silicon, zinc, manganese, and others are possible. (Cabot *et al.*, 2019).

Zinc is an essential micronutrient plays a pivotal role in modulating plant defense responses against various stressors as it serves as a cofactor for all 6 classes of enzymes (oxidoreductases, transferases, hydrolases, lyases, isomerase and ligases). Zinc (Zn) emerges as a promising candidate for enhancing rice's resistance against insect herbivores, including the yellow stem borer (Srivastrava and Gupta, 1996). Moreover, fifty per cent Indian soils are deficient in zinc (Singh, 2009) and numbers of Zn sources *viz.* ZnSO<sub>4</sub>, ZnO, Zn-EDTA have been used to eliminate zinc deficiency (Stomph *et al.*, 2011). Malandrakis *et al.* (2019) suggested foliar application of several Zn based nanoparticles (NPs) alternatives against synthetic chemicals because of their high effectiveness at low doses in controlling infestation of insect pests and are eco-friendly. In view of above background, an attempt has been made to confirm the zinc induced resistant against yellow stem borer.

## MATERIAL AND METHODS

To confirm the zinc induced resistant against yellow stem borer in rice, a field experiments were conducted during *kharif* 2022 and 2023 at N. M. College of Agriculture, Navsari Agricultural University, Navsari Gujarat (India). Field experiments were conducted in medium black clayey soil, slightly saline reaction with a pH (7.35), EC (0.38dS/m) and deficient in available-Zn (0.345 ppm). Total nine treatments were tried *viz.* T<sub>1</sub>: ZnSO<sub>4</sub> @ 25 kg/ha , T<sub>2</sub>: ZnSO<sub>4</sub> @ 50 kg/ha, T<sub>3</sub>: Zn-EDTA @ 12.5 kg/ha, T<sub>4</sub>: Zn-EDTA @ 25 kg/ha, T<sub>5</sub>: foliar application of ZnSO<sub>4</sub> @1%, T<sub>6</sub>: Foliar application of Zn- EDTA @1% , T<sub>7</sub>: foliar application of zinc nanoparticle @ 100 ppm, T<sub>8</sub>: foliar application of biosynthesis Zinc nanoparticle @ 100 ppm and T<sub>9</sub>: Control (Water spray only) to explore the mechanism of Zn induced resistance against the YSB, *S. incertulas*. The selected field was subjected to rice-fallow cropping system each year and hence, suitably trial was super imposed in the two consecutive years for getting cumulative effect of the treatments. The experiments were laid in CRD. Large plot Techniques with three replications. Rice (*var.* GR 11) was fertilized with recommended dose of NPK while, zinc fertilization were made as per treatments. Foliar application of ZnSO<sub>4</sub> and Zn-EDTA, zinc nano particle and biosynthesized Zinc nano particle as per treatments was sprayed at tillering and grain filling stage of rice. The crop was raised following all recommended agronomic practices for rice. YSB damage at the vegetative (30 and 50 DAT) and heading stage (70 DAT) was calculated from the mean data of per cent dead heart (DH) at vegetative and white ear heads (WEH) at heading stage as follows:

$$\text{Percent dead hearts (\% DH)} = \frac{\text{Total number of dead hearts} \times 100}{\text{Total number of tillers}}$$

$$\text{Percent white ear heads (\% WEH)} = \frac{\text{Total number of white heads} \times 100}{\text{Total number of panicles bearing tillers}}$$

## RESULT AND DISCUSSION

### ***Kharif 2022***

Significant effect of applied Zn through different sources was observed on damage by YSB (Table 1), right from early tillering stage (30 DAT). Significantly lower per cent of DH was recorded in treatment T<sub>2</sub> (5.46, % DH) receiving ZnSO<sub>4</sub> @ 50 kg/ha through basal soil application and was on par with the treatments T<sub>4</sub> (6.47 % DH) receiving Zn- EDTA @ 25 kg/ha through basal soil application and T<sub>8</sub> (7.18 % DH) receiving foliar application of Biosynthesis Zinc nanoparticle @ 100 ppm while, treatment T<sub>8</sub> remained on par with treatments T<sub>1</sub> (7.52 % DH) receiving ZnSO<sub>4</sub> @ 25 kg/ha through basal soil application, T<sub>3</sub> (8.14 % DH) receiving Zn-EDTA @ 12.5 kg/ha through basal soil application and T<sub>7</sub> (9.10 % DH) receiving foliar application of Zinc nanoparticle @ 100 ppm. Remaining zinc treatments T<sub>5</sub> and T<sub>6</sub> found less effective in controlling YSB damage.

The data on DH at 50 DAT revealed that treatment T<sub>2</sub> recorded significantly lower damage (8.85 % DH) and was at par with treatments T<sub>4</sub> (10.53 % DH) and T<sub>8</sub> (11.84 % DH) while, treatment T<sub>8</sub> stood on par with treatments T<sub>1</sub> (12.71% DH), T<sub>3</sub> (13.51 % DH) and T<sub>7</sub> (15.20% DH). Treatments T<sub>5</sub> and T<sub>6</sub> were found least efficient in controlling YSB damage.

Overall performance of the treatments during the vegetative stage as depicted in the mean column also exhibited the superiority of treatments T<sub>2</sub>, T<sub>4</sub>, T<sub>8</sub>, T<sub>1</sub> and T<sub>3</sub> with numerically mean borer damage of 7.15, 8.50, 9.51, 10.11 and 10.82 per cent DH attributing in 54.19, 45.55, 39.08, 35.23 and 30.68 per cent decline in borer damage over control. YSB damage at the heading stage is considered to be more critical, which contributes maximum to determining the crop yield. The performance of treatment T<sub>2</sub> in arresting the borer damage at the heading stage was superior and remained on par with treatment T<sub>4</sub> with a record of 8.70 and 10.60 per cent WEH resulting in 61.10 and 52.61 per cent decline in borer damage over control. Further, treatment T<sub>4</sub> was only at par with treatment T<sub>8</sub> having 11.94 % WEH and resulting in 46.62% decline in borer damage over control. While, remaining zinc treatments viz T<sub>1</sub>, T<sub>3</sub>, T<sub>5</sub>, T<sub>6</sub> and T<sub>7</sub> miserably failed to contain the borer damage.

### ***Kharif, 2023***

Zinc applied through different sources generated significant and promising effect in minimizing YSB destructive effect in field *kharif* rice 2023 (Table 2) right from early tillering stage (30 DAT). Significantly lowest per cent DH was noticed in treatment T<sub>2</sub> (4.54 % DH) and was on par with only treatment T<sub>4</sub> (5.31% DH) while, treatment T<sub>4</sub> remained was at par with treatment T<sub>8</sub> (6.24 % DH) only. Amongst the remaining zinc treatments, treatment T<sub>1</sub>, T<sub>3</sub>, T<sub>5</sub> and T<sub>7</sub> found less effective as compare to treatments T<sub>2</sub>, T<sub>4</sub> and T<sub>8</sub>.

At 50 DAT, the data on YSB damage revealed that treatment T<sub>2</sub> (ZnSO<sub>4</sub> @ 50 kg/ha) recorded significantly lower damage (6.96 % DH) and was at par with treatments T<sub>4</sub> (8.08 % DH) and T<sub>8</sub> (9.14 % DH). While, treatment T<sub>8</sub> stood on par with all remaining zinc treatments except T<sub>6</sub>.

Overall performance of the treatments during the vegetative stage as depicted in the mean column exhibited the superiority of treatments T<sub>2</sub>, T<sub>4</sub> and T<sub>8</sub> with numerically the lowest mean borer damage of 5.75, 6.69 and 7.69 per cent DH attributing in 57.18, 50.18 and 42.74 per cent decline in borer damage over control. Treatments T<sub>1</sub>, T<sub>3</sub>, T<sub>7</sub>, T<sub>5</sub> and T<sub>6</sub> failed to contain the borer damage.

At the heading stage, treatment T<sub>2</sub> (ZnSO<sub>4</sub> @ 50 kg/ha) produced significantly the lowest YSB damage (5.68% WEH) resulting in 64.84% decline in borer damage over control. Next better treatment was T<sub>4</sub> (8.13 % WEH)

showing 60.68% decline in borer damage over control and stood on par with treatments T<sub>8</sub> (9.34% WEH), T<sub>1</sub> (8.82% WEH) T<sub>3</sub> (9.59% WEH) and T<sub>7</sub> (10.61% WEH) having 50.92, 41.82, 36.74 and 30.01 per cent decline in borer damage over control, respectively. Remaining zinc treatments *viz.* T<sub>5</sub> and T<sub>6</sub> failed to hold the borer damage.

### **Pooled**

Pooled data revealed the overall performance of the treatments over two *kharif* seasons highlighting efficacy of zinc treatments in keeping the YSB damage in control both at vegetative and heading (reproductive) stages of the rice crop (Table 3). The pooled data confirmed the superiority of treatment T<sub>2</sub> (ZnSO<sub>4</sub> @ 50 kg/ha) as it registered minimum damage (5.00% DH) at early vegetative stage (30 DAT) and 7.90% DH damage at late vegetative stage (50 DAT). Next better treatments were T<sub>4</sub> and T<sub>8</sub> which also registered lower damage 5.89 and 6.71 per cent DH at early vegetative stage (30 DAT) and 9.30 and 10.48 per cent DH at late vegetative stage (50 DAT), respectively and stood on par among themselves. While, remaining zinc treatments *viz.* T<sub>1</sub>, T<sub>3</sub>, T<sub>7</sub>, T<sub>5</sub> and T<sub>6</sub> were found less effective in arresting YSB damage.

Overall performance of the treatments during the vegetative stage as depicted in the mean column exhibited the superiority of treatments T<sub>2</sub>, T<sub>4</sub> and T<sub>8</sub> with numerically the lowest mean borer damage of 6.45, 7.60 and 8.60 per cent DH attributing in 55.61, 47.69 and 40.81 per cent decline in borer damage over control, respectively. While, remaining zinc treatments *viz.* T<sub>1</sub>, T<sub>3</sub>, T<sub>7</sub>, T<sub>5</sub> and T<sub>6</sub> found less effective in arresting YSB damage.

At the heading stage the treatment T<sub>2</sub> noted minimum damage (7.01% WEH) having 62.63% decline in borer damage. Next better treatments were T<sub>4</sub> (8.28 % WEH) and T<sub>8</sub> (9.69 % WEH) resulting in 55.86 and 48.35 per cent decline in borer damage respectively. While, remaining zinc treatments *viz.* T<sub>1</sub>, T<sub>3</sub>, T<sub>5</sub>, T<sub>6</sub> and T<sub>7</sub> failed to hold the borer damage in rice.

Zinc induced resistant against YSB might be due to antibiosis effect of applied zinc on rice plant. Zn being an essential element plays a key role as a structural constituent, triggers the synthesis of defensive compounds which act as chemical shields against herbivores, Zn content is directly involved in plant defense mechanism enhancing rice's resistance against insect herbivores (Helfenstein *et al.*, 2015 and Devasena *et al.*, 2018). Panda (1976) and Amsagowri *et al.* (2019) reported the antagonistic indirect effect of zinc against yellow stem borer due to induced antibiosis effect of zinc and developing of hard *pseudostem*. Sardar *et al.*, (2020) confirmed the superiority of soil application of ZnSO<sub>4</sub> @ 10 kg/ha over chelated zinc (Zn- EDTA) and 0.5% foliar application of zinc alone. Malandrakis *et al.* (2019) suggested foliar application of several Zn based nano particles (NPs) alternatives against synthetic chemicals because of their high effectiveness at low doses in controlling infestation of insect pests and are eco-friendly. Further, in present investigation, higher doses of either ZnSO<sub>4</sub> @ 50 kg/ha (T<sub>2</sub>) or Zn- EDTA @ 25.0 kg/ha (T<sub>4</sub>) found more effective than recommended doses of ZnSO<sub>4</sub> or Zn-EDTA for rice might be due to present rice variety was grown in Zn deficient field (0.395 ppm) hence application of zinc at higher rate might provides balanced nutrition to rice (Sardar *et al.*, 2020).

### **Zinc content:**

Zinc content from whole rice plant was chemically analyzed at vegetative, heading and at harvest and results are depicted in table 4. Significantly higher Zn content was noticed in treatment T<sub>2</sub> at all stages *i.e.* vegetative (119.00ppm), heading (117.30 ppm) and at harvest stage (107.33 ppm) in field rice and was statistically on par with

all remaining zinc treatments except, T<sub>6</sub> and T<sub>7</sub> at vegetative and harvest stages and T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub> and T<sub>8</sub> at heading stage. Results are in agreement with Dwivedi and Srivastva (2014) who noticed that the application of 25 kg ZnSO<sub>4</sub>/ha significantly increased 70.9% and 50.7 % zinc concentration in grain and straw of rice, respectively and Ahmed *et al.* (2022) registered maximum increase of 66% Zn concentration in rice leaves and 127% increase in rice grain content over control with application of 15.0 kg Zn/ha through ZnSO<sub>4</sub>.

### Correlation:

YSB damage was significantly and negatively correlated at vegetative ( $r = -0.64^{**}$ ) and heading stage ( $r = -0.67^{**}$ ) with zinc content (Table 5). Significant and negative correlation between Zn content and YSB damage was computed at vegetative and heading stages might be due to reason that high Zn concentration in plant tissues is potentially toxic to all insect pests (Shu *et al.*, 2012; Bala *et al.*, 2019).

### Conclusion

Application of zinc at higher rates (ZnSO<sub>4</sub> @ 50 kg/ha, Zn-EDTA @ 25 kg/ha) and foliar application of bio-synthesized zinc NPs were found to be the most promising in enhancing the induction of resistance in rice plants against its most notorious pest, *S. incertulas* and promote Zn accumulation content. ZnSO<sub>4</sub> in particular could be considered as a potential source of Zn as it is cheap and easily available in the nearby locality. Thus, the present study emphasizes on use of this zinc source for the management of rice pests in general and yellow stem borer in particular.

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**Table1: Effect of different zinc sources on damage caused by yellow stem borer in rice field (kharif-2022).**

No.	Treatments	Damage at vegetative stage (DH%)				Damage at heading stage(%WEH)	
		30 DAT	50 DAT	Mean	Decrease over control (%)	Heading stage	Decrease over control (%)
T <sub>1</sub>	Zinc Sulphate @ 25 kg/ha	7.52 (2.83)	12.71 (3.62)	10.11 (3.22)	35.23	15.23 (3.96)	31.78
T <sub>2</sub>	Zinc Sulphate @ 50 kg/ha	5.46 (2.43)	8.85 (3.05)	7.15 (2.74)	54.19	8.70 (3.02)	61.10
T <sub>3</sub>	Zinc EDTA @ 12.5 kg/ha	8.14 (2.94)	13.51 (3.74)	10.82 (3.33)	30.68	16.20 (4.08)	27.58
T <sub>4</sub>	Zinc EDTA @ 25 kg/ha	6.47 (2.63)	10.53 (3.31)	8.50 (2.97)	45.55	10.60 (3.33)	52.61
T <sub>5</sub>	Foliar application of Zinc Sulphate @ 1%	9.34 (3.14)	16.22 (4.08)	12.78 (3.61)	18.13	19.08 (4.41)	14.70
T <sub>6</sub>	Foliar application of Zinc EDTA @ 1%	9.84 (3.21)	16.56 (4.13)	13.20 (3.66)	15.43	19.80 (4.50)	11.49
T <sub>7</sub>	Foliar application of Zinc nanoparticle (100 ppm)	9.10 (3.10)	15.20 (3.96)	12.15 (3.53)	22.23	18.00 (4.30)	19.53
T <sub>8</sub>	Foliar application of Biosynthesis Zinc nanoparticle (100 ppm)	7.18 (2.76)	11.84 (3.51)	9.51 (3.13)	39.08	11.94 (3.52)	46.62
T <sub>9</sub>	Control (Water spray)	12.20 (3.56)	19.04 (4.42)	15.62 (3.98)	0.00	22.37 (4.77)	0.00
	Mean	<b>8.36</b> <b>(2.96)</b>	<b>13.38</b> <b>(3.56)</b>	<b>11.09</b> <b>(3.35)</b>	-	<b>15.77</b> <b>(3.99)</b>	-
	S.E.m ±	0.12	0.15	-	-	0.17	-
	C.D. <sub>0.05</sub>	0.34	0.46	-	-	0.49	-
	CV (%)	6.77	7.08	-	-	7.19	-

**Table 2: Effect of different zinc sources on damage caused by yellow stem borer in rice field (*kharif*- 2023).**

No.	Treatments	Damage at vegetative stage (DH%)				Damage at heading stage(%WEH)	
		30 DAT	50 DAT	Mean	Decrease over control (%)	Heading stage	Decrease over control (%)
T <sub>1</sub>	Zinc Sulphate @ 25 kg/ha	7.35 (2.80)	9.49 (3.15)	8.42 (2.97)	37.30	8.82 (3.05)	41.82
T <sub>2</sub>	Zinc Sulphate @ 50 kg/ha	4.54 (2.23)	6.96 (2.72)	5.75 (2.48)	57.18	5.33 (2.41)	64.84
T <sub>3</sub>	Zinc EDTA @ 12.5 kg/ha	8.16 (2.94)	10.53 (3.31)	9.34 (3.13)	30.45	9.59 (3.17)	36.74
T <sub>4</sub>	Zinc EDTA @ 25 kg/ha	5.31 (2.39)	8.08 (2.93)	6.69 (2.66)	50.18	5.96 (2.54)	60.68
T <sub>5</sub>	Foliar application of Zinc Sulphate @ 1%	9.32 (3.13)	11.38 (3.44)	10.35 (3.29)	22.93	11.52 (3.47)	24.01
T <sub>6</sub>	Foliar application of Zinc EDTA @ 1%	9.97 (3.23)	12.27 (3.57)	11.12 (3.40)	16.46	12.40 (3.58)	18.20
T <sub>7</sub>	Foliar application of Zinc nanoparticle (100 ppm)	8.23 (2.95)	11.08 (3.40)	9.66 (3.18)	28.07	10.61 (3.33)	29.15
T <sub>8</sub>	Foliar application of Biosynthesis Zinc nanoparticle (100 ppm)	6.24 (2.59)	9.14 (3.10)	7.69 (2.85)	42.74	7.44 (2.81)	50.92
T <sub>9</sub>	Control (Water spray)	11.42 (3.45)	15.43 (3.99)	13.43 (3.72)	0.00	15.16 (3.95)	0.00
	<b>Mean</b>	<b>7.84 (2.86)</b>	<b>10.48 (3.29)</b>	<b>9.16 (3.03)</b>	-	<b>9.65 (3.14)</b>	-
	S.E.m ±	0.12	0.15	-	-	0.17	-
	C.D. <sub>0.05</sub>	0.34	0.46	-	-	0.49	-
	CV (%)	6.77	7.08	-	-	7.19	-

**Table 3: Pooled effect of different zinc sources on damage caused by yellow stem borer in rice field over seasons.**

No.	Treatments	Damage at vegetative stage (DH%)				Damage at heading stage(% WEH)	
		30 DAT	50 DAT	Mean	Decrease over control (%)	Heading stage	Decrease over control (%)
T <sub>1</sub>	Zinc Sulphate @ 25 kg/ha	7.43 (2.81)	11.09 (3.38)	9.26 (3.12)	36.27	12.02 (3.51)	35.93
T <sub>2</sub>	Zinc Sulphate @ 50 kg/ha	5.00 (2.32)	7.90 (2.88)	6.45 (2.63)	55.61	7.01 (2.71)	62.63
T <sub>3</sub>	Zinc EDTA @ 12.5 kg/ha	8.14 (2.93)	12.01 (3.52)	10.08 (3.25)	30.63	12.89 (3.63)	31.29
T <sub>4</sub>	Zinc EDTA @ 25 kg/ha	5.89 (2.51)	9.30 (3.12)	7.60 (2.84)	47.69	8.28 (2.93)	55.86
T <sub>5</sub>	Foliar application of Zinc Sulphate @ 1%	8.66 (3.13)	13.80 (3.76)	11.23 (3.42)	22.71	15.30 (3.94)	18.44
T <sub>6</sub>	Foliar application of Zinc EDTA @ 1%	9.33 (3.22)	14.41 (3.84)	11.87 (3.51)	18.31	16.09 (3.04)	14.23
T <sub>7</sub>	Foliar application of Zinc nanoparticle (100 ppm)	8.66 (3.02)	13.14 (3.68)	10.90 (3.37)	24.98	14.30 (3.81)	23.77
T <sub>8</sub>	Foliar application of Biosynthesis Zinc nanoparticle (100 ppm)	6.71 (2.67)	10.48 (3.30)	8.60 (3.01)	40.81	9.69 (3.16)	48.35
T <sub>9</sub>	Control (Water spray)	11.81 (3.50)	17.24 (4.20)	14.53 (3.87)	0.00	18.76 (4.36)	0.00
	<b>Mean</b>	<b>7.95 (2.90)</b>	<b>12.15 (3.52)</b>	<b>10.06 (3.22)</b>	-	<b>12.70 (3.45)</b>	-
	S.E.m ±	0.06	0.07	-	-	0.69	-
	C.D. <sub>0.05</sub>	0.18	0.22	-	-	2.07	-
		<b>C.D.<sub>0.05</sub></b>	<b>C.D.<sub>0.05</sub></b>	<b>C.D.<sub>0.05</sub></b>	-	<b>C.D.<sub>0.05</sub></b>	-
	Y	NS	NS	-	-	NS	-
	YxT	NS	NS	-	-	NS	-
	CV (%)	5.59	5.48	-	-	7.60	-

**Table 4: Effect of different zinc sources on Zn content at different growth stages of field rice (Var. GR 11).**

No.	Treatments	Zn content (ppm)		
		Vegetative stage	Heading stage	At harvest
T <sub>1</sub>	Zinc Sulphate @ 25 kg/ha	114.00	112.00	101.00
T <sub>2</sub>	Zinc Sulphate @ 50 kg/ha	119.00	117.30	107.33
T <sub>3</sub>	Zinc EDTA @ 12.5 kg/ha	112.67	110.00	100.67
T <sub>4</sub>	Zinc EDTA @ 25 kg/ha	117.00	114.66	109.00
T <sub>5</sub>	Foliar application of Zinc Sulphate @ 1%	107.33	105.33	96.63
T <sub>6</sub>	Foliar application of Zinc EDTA @ 1%	103.00	101.67	98.00
T <sub>7</sub>	Foliar application of Zinc nanoparticle (100 ppm)	105.58	103.43	97.00
T <sub>8</sub>	Foliar application of Biosynthesis Zinc nanoparticle (100 ppm)	107.60	106.25	99.67
T <sub>9</sub>	Control (Water spray)	80.69	77.28	79.33
	<b>Mean</b>	<b>107.44</b>	<b>105.38</b>	<b>98.74</b>
	S.E.m ±	4.01	3.32	3.64
	C.D. <sub>0.05</sub>	11.92	9.87	10.83
	CV (%)	6.47	5.47	6.39

**Table 5 : Correlation between Zn content and YSB infestation at vegetative and heading stage.**

Correlation study parameters	Correlation coefficient (r)
Zn content Vs YSB damage at vegetative stage(DH)	-0.64**
Zn content Vs YSB damage at heading stage (WEH)	-0.67**

Significance level: 0.381 (0.05), 0.487 (0.1)

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