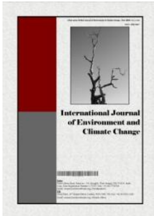

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Effect of Spacing and dosage of Nitrogen against the Maydis Leaf Blight Disease of Maize

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Maize is one of the most important cereal crops in the world. It belongs to family, "Poaceae". It has wider adaptability under different agro-climatic conditions. Its productivity per unit area is very high, so it is called "queen of cereals" globally. Though, Crop has high food and economic value, its production is limited by many constraints including the diseases also. Maydis leaf blight (MLB) is found almost everywhere maize is grown. It is caused by fungus *Helminthosporium maydis*. This disease is highly destructive in hot, humid and tropical climates of the world. In present investigation field trial was conducted to evaluate the effect of Spacing and Nitrogen dosages thereby managing the disease. The layout of this field experiment was in split plot design and conducted for the year 2019 and 2020 *Kharif* comprising of spacing: 45x20 cm, 60x20 cm and 75x20 cm and nitrogen dosages: 120, 160, 200 and 240 kg/ha as treatment with three replications. Results show that during 2019, the lowest PDI was obtained with the spacing of S3 (75x20 cm), which was significantly superior to all the spacing thereby reducing disease severity. The PDI was significantly influenced by nitrogen levels too. Lowest PDI (54.06 %) was obtained with the N3 (200

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kg/ha), significantly superior to N2 and N1 levels of nitrogen fertilizer. There was also a significant interaction between spacing and nitrogen levels. Similar results were obtained during 2020 and for pool data that has also been calculated for the year *Kharif* 2019-2020. During the year, 2019 and 2020 grain yield was significantly influenced by spacing and nitrogen level too but the interaction was not significant.

Keywords: Disease severity; grain yield; maize; maydis leaf blight; nitrogen dosage; PDI; spacing and split plot.

1. INTRODUCTION

Maize or corn (*Zea mays* L. 2N=20) is one of the most important cereal crops in the world. It belongs to tribe Maydeae from grass family, "Poaceae". Maize, a native of South America [1,2] is the most versatile crop and is grown in more than 150 countries. It was introduced to India by Portuguese at about the beginning of the 17th century. Now it is one of the important cereals in India.

It is one of the most emerging crops having wider adaptability under different agro-climatic conditions. It is mainly a tropical crop, but also has well adapted to temperate conditions. Maize is third to wheat and rice in world food production (Meena and Meena, 2006). However, as far as productivity is concerned it ranks first. On account of its growing demand for diversified uses, it is gaining significant importance especially in the feed and industrial sector uses. In India, it is mainly grown in Karnataka, Andhra Pradesh, Maharashtra, Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh and Punjab. Area wise distribution of maize in Indiais shown in Fig. 1. Maize is known as 'Queen of cereals' because of its high genetic yield potential. It is also a cheap source for the production of syrups, oils, starch,dextrose etc. Corn oil is extracted from the embryo of corn. It contains rich amount of linoleic acid. Sufficient quantities of vitamin A, nicotinic acid, riboflavin and vitamin E are also present in maize grains. Continued growth in the poultry and starch industry will support the higher consumption of maize in India [3]. Due to increasing demand, Maize production in India was 27.23 million tons from an area of 9.18 million hectare area with the productivity of 2965 kg per hectare during 2018-19 [4]. Bihar has become pioneer state in maize with the production of (3.02 mt) in area of 0.68 (mha) which contribute the highest productivity of 4451 kg/ha [4]. Though, Crop has high food and economic value, its production is limited by many constraints including the diseases. More than 115 diseases of maize have so far been reported from all over the world whereas about 65 are known to occur in India leading to about 9% yield losses in maize due to diseases [5].

Maydis leaf blight (MLB) is found almost everywhere maize is grown. MLB is caused by pathogen *Bipolaris maydis* (Y. Nisik., & C. Miyake) Shoemaker, also known as *Helminthosporium maydis* (Nisik.). The pathogen *Helminthosporium maydis* (Nisik.) [Teleomorph: *Cochliobolus heterostrophus* (Drechsler)] has been reported to have three races, viz. race 'T', 'O' and 'C'. Race 'T' is very specific, causing disease on Texas cytoplasm Male Sterile (TcMS) lines which is highly virulent, having a historical importance of causing a major epidemic of southern corn leaf blight in the USA because of its extreme susceptibility and wide use of Texas Male Sterile lines (Misra, 1979). Maydis leaf blight of maize caused by *Helminthosporium maydis* is a serious threat in maize growing areas of Bihar also. This disease is highly destructive in hot, humid and tropical climates of the world. MLB is a multiple cycle disease so that it is highly dependent upon sporulation from other spots or lesions in warm (20-32^{0}C) and moderately humid environment. (Blanco and Nelson, 1972) reported that the fungus is having higher saprophytic ability and hence high primary inoculums level will be there in areas with high disease occurrence [6,7]. Less plant population and poor nutrient management practices are disease causing and yield reducing factor in maize. Both thicker and thinner plant density than the recommended ones for a normal production system reduces economic yield as well as enhances disease occurence. Low nutrients supplied may not be sufficient to exploit the genetic potential of maize [8-10]. Therefore, a field study was undertaken with the objective 'To explore the effect of spacing and nitrogen dosage level on disease index of maydis leaf blight and yield of maize' to determine the optimum spacing and nitrogen level for maize at research farm of TCA, Dholi, Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India.

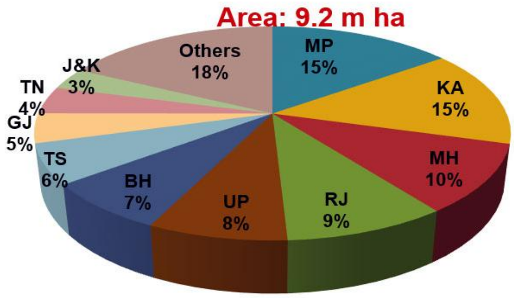

Fig. 1. Area distribution under maize cultivation for different states of India (2019)

2. MATERIALS AND METHODS

Field experiment was conducted, to evaluate the effect of spacing and nitrogen dosages on the disease. Field trials were conducted during 2019 and 2020 *Kharif* season at TCA Dholi research farm of Rajendra Prasad Central agricultural University, Pusa, Bihar, India. Field experiments were laid out in Split plot design (SPD) with twelve treatments in which spacing was considered as a main plot and nitrogen dose as sub plot using susceptible variety CML 186. Plot size was 4.5 m x 4.2 m with three different spacing and four different nitrogen dosage levels shown in Table 1. Treatments were replicated thrice.

Table 1. Spacing and nitrogen fertilizer levels

Spacing (cm)	Nitrogen dosage (Kg/ha)
45 x 20	120, 160, 200, 240
60 x 20	120, 160, 200, 240
75 x 20	120, 160, 200, 240

2.1 Dosages of Nitrogen and Spacing

The nitrogen application was done at 0, 35, 60 days after sowing. Border rows of the maize plants artificially inoculated by pathogen in 30 days after sowing. Disease severity observations measured through disease rating scale 0 to 9.

2.2 Per Cent Disease Index (PDI)

First appearance of disease and further progress of disease was recorded at 10 days interval using the new Disease rating assessment key of Maydis leaf blight given by Balint-Kurti et al., (2006), Chung et al., (2010) and Mitiku et al., (2014) that is shown in Table 2.

2.3 Grain Yield

Yield for each treatment was recorded in both the *Kharif* years (2019 and 2020). Each plot was harvested when the maize were completely dried on the field and packed in labelled bags. Thereafter, threshing was done manually before drying the grains to constant weight. Data of yield per plot (kg/plot) was recorded and then converted to yield in kg/ha. The final weighing was done to determine the actual yield in kg/plot. The data were extrapolated to kg/ha by multiplying by a constant (529.10) obtained from the ratio of the area of a hectare (10,000 m^2) to the area of the plot per treatment (4.5 × 4.2 m^2).

3. RESULTS

3.1 Effect of Spacing and Nitrogen Dosages on the Per Cent Disease Index

During 2019, from the Table 3 the result showed that the PDI was significantly influenced by spacing. The lowest PDI was obtained with the spacing of S3 (75x20 cm), which was significantly superior to all the spacing, followed by S2 (60x20 cm) and the highest PDI was obtained with the spacing of S1 (45x20 cm). The PDI was significantly influenced by nitrogen levels. The lowest PDI (54.06 %) was obtained with the N3 (200 kg/ha), which was at par with the N4 (240 kg/ha) and significantly superior to N2 (160 kg/ha) and N1 (120 kg/ha) levels of nitrogen fertilizer. There was also a significant interaction betweenspacingand nitrogen levels. When Sub (Nitrogen doses) at same level of main plot (spacing, S1), N3 is significantly superior (PDI, 60.21%) over N1and non significant to N2 and N4 as critical difference is more than the difference between the treatments. Similarly, at Spacing S2; N4 is superior over (PDI, 53.33%)N1 and N2 and at Spacing S3; N3 is superior (PDI, 44.44%) over N1.When main (spacing) at same level of sub (Nitrogen dose, N1), S3 was significantly superior (PDI, 51.10%) over S2 and S3.Similarly, at N2; S3 was again significantly superior (PDI 46.66%) over S1 and S2. At N3 and N4; S3 was again significantly superior over other spacing.

Table 2. Standard disease rating scale for maydis leaf blight of maize

Rating scale	Degree of infection (Per cent DLA*)	PDI**	Disease reaction
1.0	Nil to very slight infection (≤ 10%).	≤11.11	
2.0	Slight infection, a few lesions scattered on two lower leaves (10.1-20%).	22.22	Resistant (R)
3.0	Light infection, moderate number of lesions scattered on four lower leaves (20.1-30%).	33.33	(Score: ≤3.0) (DLA: ≤ 30%) PDI: ≤33.33)
4.0	Light infection, moderate number of lesions scattered on lower leaves, a few lesions scattered on middle leaves below the cob (30.1-40%).	44.44	Moderately resistant (MR)
5.0	Moderate infection, abundant number of lesions scattered on lower leaves, moderate number of lesions scattered on middle leaves below the cob (40.1-50%).	55.55	(Score: 3.1- 5.0) (DLA: ≤ 30.1-50%) PDI: 33.34 -55.55)
6.0	Heavy infection, abundant number of lesions scattered on lower leaves, moderate infection on middle leaves and a few lesions on two leaves above the cob (50.1-60%). 66	66.66	Moderately susceptible (MS) (Score: 5.1- 7.0) (DLA: ≤ 50.1-70%)
7.0	Heavy infection, abundant number of lesions scattered on lower and middle leaves and moderate number of lesions on two to four leaves above the cob (60.1-70%).	77.77	PDI: 55.56 -77.77)
8.0	Very heavy infection, lesions abundant scattered on lower and middle leaves and spreading up to the flag leaves (70.1-80%).	88.88	Susceptible (S) (Score: > 7.0)
9.0	Very heavy infection, lesions abundant scattered on almost all the leaves, plants prematurely dried and killed (>80%).	99.99	(DLA:>70%) PDI: >77.77)

** DLA- Diseased leaf area; **Per cent disease index (PDI)*

Table 3. Effect of Spacing and Nitrogen fertilizer doses on the per cent disease index of maydis leaf blight disease of maize during the year *Kharif* 2019 and 2020

PDI (2019)					
Spacing (cm)	**Nitrogen dose (Kg/ha)**				
	***N1**	**N2**	**N3**	**N4**	**Mean A**
***S1**	76.29 (60.87)	64.44 (53.37)	60.21 (52.05)	62.26 (52.08)	**66.29 (54.59)**
S2	71.84 (57.95)	61.47 (51.62)	55.55 (48.16)	53.33 (46.89)	**60.55 (51.16)**
S3	51.10 (45.61)	46.66 (43.06)	44.44 (41.78)	48.88 (44.34)	**47.77 (43.70)**
Mean B	**66.41 (54.81)**	**57.52 (49.35)**	**54.06 (47.33)**	**54.80 (47.76)**	**-**
Factors	**C D (5%)**		**SEm±**	-	-
Factor A	1.25 (0.80)		0.31 (0.19)	-	-
Factor B	2.63 (1.60)		0.87 (0.53)	-	-
Factor B at same level of A	4.64 (2.82)		0.62 (0.39)	-	-
Factor A at same level of B	4.12 (2.52)		1.35 (0.82)	-	-

PDI (2020)					
Spacing (cm)	**Nitrogen dose (Kg/ha)**				
	***N1**	**N2**	**N3**	**N4**	**Mean A**
***S1**	82.21 (65.05)	75.55 (60.35)	71.10 (57.47)	74.81 (59.39)	**75.73 (60.57)**
S2	77.03 (61.37)	74.06 (59.39)	65.44 (53.37)	60.99 (50.76)	**68.88 (56.22)**
S3	64.44 (53.37)	62.21 (52.05)	53.33 (46.89)	58.51 (49.89)	**59.62 (50.55)**
Mean B	**74.56 (59.93)**	**70.61 (57.26)**	**62.95 (52.58)**	**64.19 (53.34)**	**-**
Factors	**C D (5%)**		**SEm±**	-	-
Factor A	5.43 (3.46)		1.34 (0.86)	-	-
Factor B	2.29 (1.42)		0.76 (0.47)	-	-
Factor B at same level of A	4.77 (2.97)	-	2.69 (1.72)	-	-
Factor A at same level of B	6.36 (4.03)	-	1.77 (1.11)	-	-

POOLED PDI (2019-2020)					
Spacing (cm)	**Nitrogen dose (Kg/ha)**				
	***N1**	**N2**	**N3**	**N4**	**Mean A**
***S1**	79.25 (63.06)	69.99 (56.51)	65.65 (54.02)	68.53 (55.80)	**70.85 (57.35)**
S2	74.43 (59.68)	67.76 (55.29)	60.49 (50.99)	57.16 (49.18)	**64.96 (53.78)**
S3	57.77 (49.33)	54.43 (47.59)	48.88 (44.26)	53.69 (46.99)	**53.69 (47.04)**
Mean B	**70.48 (57.36)**	**64.06 (53.13)**	**58.34 (49.76)**	**59.79 (50.66)**	**-**
Factors	**C D (5%)**		**SEm±**	-	-
Factor A	1.63 (0.83)		0.40 (0.20)	-	-
Factor B	0.86 (0.51)		0.29 (0.17)	-	-
Factor B at same level of A	1.74 (1.02)		0.81 (0.41)	-	-
Factor A at same level of B	2.06 (1.12)		0.59 (0.33)	-	-

*Values in parenthesis are angular transformed values. *S1 - 45 x 20 cm, S2 - 60 x 20 cm, S3 -75 x 20 cm; N1 - 120 kg/ha, N2 - 160 kg/ha, N3 - 200 kg/ha, N4 - 240kg/ha*

During 2020, the result showed that the PDI was significantly influenced by spacing. The lowest PDI (59.62%) was obtained with the spacing of S3 (75x20 cm), which was significantly superior to all the spacing, followed by S2 (60x20 cm) and S1 (45x20 cm). The PDI was significantly influenced by nitrogen levels too. The lowest PDI (62.95%) was obtained with the N3 (200 kg/ha), which was at par with the N4 (240 kg/ha) and significantly superior to N2 (160 kg/ha) and N1 (120 kg/ha) levels of nitrogen fertilizer. There was also a significant interaction between spacing and nitrogen levels. When Sub (Nitrogen doses) at same level of main plot (spacing, S1), N3 was significantly superior (PDI, 71.10%) over N1 and non significant to N2 and N4 as critical difference is more than the difference between the treatments. Similarly, at Spacing S2; N4 is superior over (PDI, 60.99%) N1, N2 and N4 and at Spacing S3; N3 is superior (PDI, 53.33%) over N1, N2 and N4.When main (spacing) at same level of sub (Nitrogen dose, N1), S3 was significantly superior over S1 and S2. At N2 and N3; S3 again was significantly superior over S1 and S2. At N4; S3 and S2 was at par and S3 significantly superior over S1 was shown in Fig. 2.

From the Pool data (*Kharif* 2019-2020) the result revealed that the PDI was significantly influenced by spacing. The lowest PDI (53.69%) was obtained with the spacing of S3 (75x20 cm), which was significantly superior to all the spacing, followed by S2 (60x20 cm) and S1 (45x20 cm). The PDI was significantly influenced by nitrogen levels. The lowest PDI (58.34%) was obtained with the N3 (200 kg/ha), which was at par with the N4 (240 kg/ha) and significantly superior to N2 (160 kg/ha) and N1 (120 kg/ha) levels of nitrogen fertilizer. There was also a significant interaction between spacing and nitrogen levels. When Sub (Nitrogen doses) at same level of main plot (spacing, S1), N3 was significantly superior (PDI, 65.65%) over N1, N2 and N4. Similarly, at Spacing S2; N4 is superior over (PDI, 57.16%) all other nitrogen levels. At Spacing S3; N3 was superior (PDI, 48.88%) over all nitrogen levels. When main (spacing) at same level of sub (Nitrogen dose i.e. N1, N2, N3 and N4), S3 was significantly superior over all other spacing shown in Table 3 and Fig. 2.

3.2 Effect of Spacing and Nitrogen Fertilizer Doses on the Grain Yield of Maize

During 2019, form the Table 4 the results revealed that the grain yield was significantly influenced by spacing. The highest grain yield (46.03 q/ha) was obtained with the spacing of S3 (75x20 cm), which was significantly superior to all the spacing, followed by S2 (60x20 cm) and S1 (45x20 cm). The grain yieldwas significantly influenced by nitrogen levels. The highest grain yield (44.21 q/ha) was obtained with the N4 (240 kg/ha), which was at par with the N3 (200 kg/ha) and significantly superior to N1 (120 kg/ha) level of nitrogen fertilizer. There was not any significant interaction between spacing and nitrogen levels.

During 2020, the result revealed that the grain yield was not significantly influenced by spacing but significantly influenced by nitrogen levels. The highest grain yield (44.66 q/ha) was obtained with the N4 (240 kg/ha), which was significantly superior over all other levels of nitrogen fertilizer. There was not any significant interaction between spacing and nitrogen levels (Fig. 3).

From the Pool data (*Kharif* 2019-2020) the result revealed that the grain yield was significantly influenced by spacing. The highest grain yield (45.10 q/ha) was obtained with the spacing of S3 (75x20 cm), which was significantly superior to all the spacing, followed by S2 (60x20 cm) and S1 (45x20 cm). The grain yield was significantly influenced by nitrogen levels. The highest grain yield (44.87 q/ha) was obtained with the N4 (240 kg/ha), which was significantly superior to all other nitrogen levels. Grain yield values are at par in N2 (160 kg/ha) and N3 (120 kg/ha) levels of nitrogen fertilizer. There was also a significant interaction betweenspacing and nitrogen levels. When Sub (Nitrogen doses) at same level of main plot (spacing, S1), N4 was significantly superior (44.07 q/ha) over N1, N2 and N3. Similarly, at Spacing S2; N4 is superior over all other nitrogen doses. At Spacing S3; N3 was superior (46.20 q/ha) over all other nitrogen doses. When main (spacing) at same level of sub (Nitrogen dose), S3 was significantly superior over all other spacing shown in Table 4 and Fig. 3.

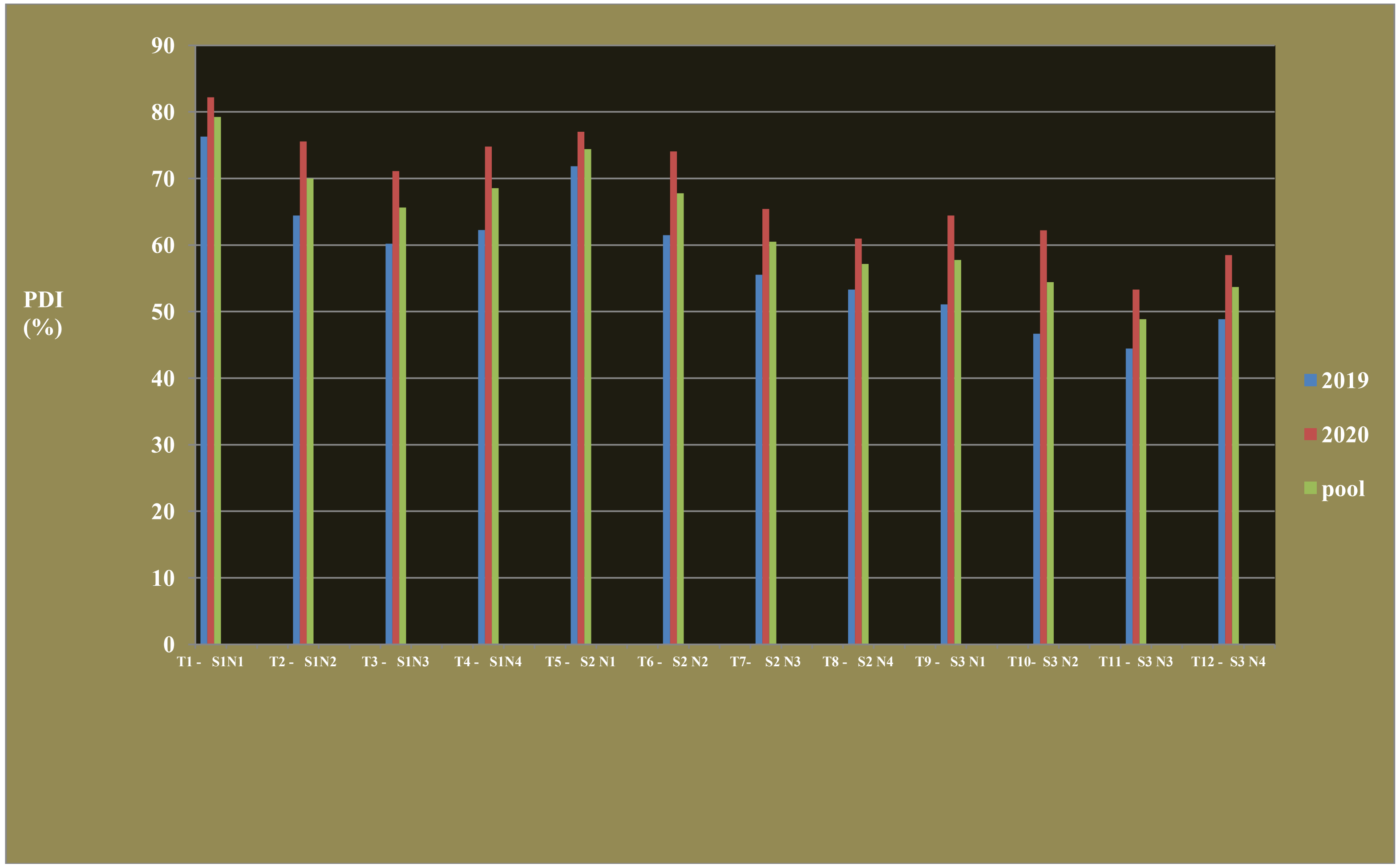

Fig. 2. Effect of Spacing and Nitrogen fertilizer doses on the per cent disease index of maydis leaf blight disease of maize during the year *Kharif* 2019 and 2020

S1 - 45 x 20 cm, S2 - 60 x 20 cm, S3 -75 x 20 cm; N1 - 120 kg/ha, N2 - 160 kg/ha, N3 - 200 kg/ha, N4 - 240kg/ha

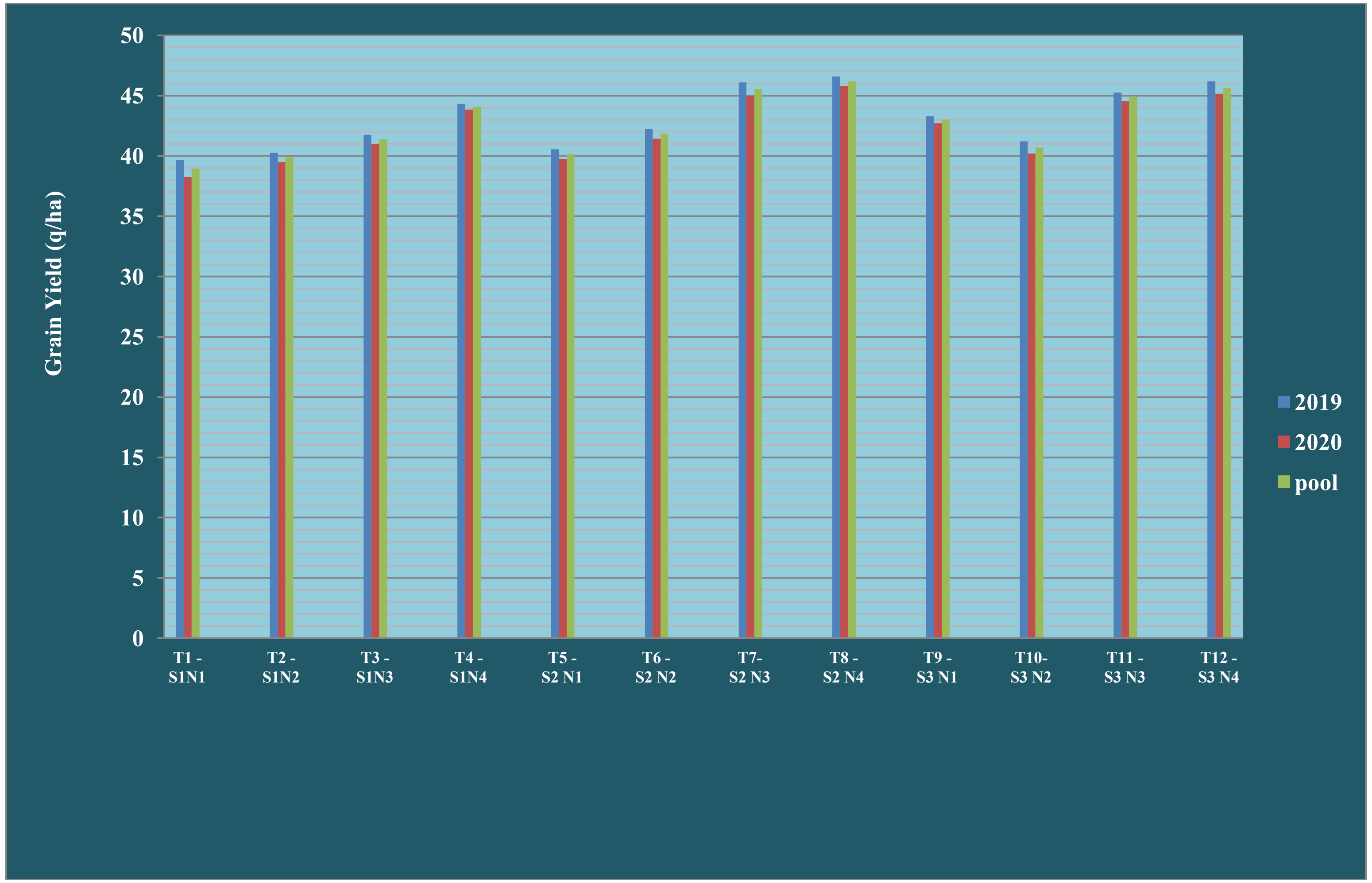

Fig. 3. Effect of Spacing and Nitrogen fertilizer doses on the grain yield of maize during the year *Kharif* 2019 and 2020

S1 - 45 x 20 cm, S2 - 60 x 20 cm, S3 -75 x 20 cm; N1 - 120 kg/ha, N2 - 160 kg/ha, N3 - 200 kg/ha, N4 - 240kg/ha

Table 4. Effect of Spacing and Nitrogen fertilizer doses on the grain yield of maize during the year *Kharif* 2019 and 2020

Gain Yield(q/ha) (2019)						Grain Yield(q/ha) (2020)						Pooled Grain Yield(q/ha) (2019-2020)					
Spacing (cm)	**Nitrogen dose (Kg/ha)**					**Spacing (cm)**	**Nitrogen dose (Kg/ha)**					**Spacing (cm)**	**Nitrogen dose (Kg/ha)**				
	***N_1**	**N_2**	**N_3**	**N_4**	**Mean A**		***N_1**	**N_2**	**N_3**	**N_4**	**Mean A**		***N_1**	**N_2**	**N_3**	**N_4**	**Mean A**
***S_1**	39.65	40.28	41.75	42.25	**40.98**	***S_1**	38.25	39.50	41.00	43.85	**40.65**	***S_1**	38.95	39.89	41.37	44.07	**41.07**
S_2	40.56	41.20	43.31	44.30	**42.34**	**S_2**	39.75	41.43	40.20	45.00	**41.59**	**S_2**	40.15	41.84	40.70	44.90	**41.89**
S_3	45.25	46.18	46.60	46.10	**46.03**	**S_3**	42.72	44.55	45.80	45.15	**44.55**	**S_3**	43.01	45.55	46.20	45.66	**45.10**
Mean B	**41.82**	**42.55**	**43.88**	**44.21**	-	**Mean B**	**40.24**	**41.82**	**42.33**	**44.66**	-	**Mean B**	**40.70**	**42.42**	**42.75**	**44.87**	-
Factors	**C D (5%)**		**SEm±**	**-**	-	**Factors**	**C D (5%)**		**SEm±**	-	-	**Factors**	**C D (5%)**		**SEm±**	-	-
Factor A	1.90		0.46	-	-	Factor A	N/A		0.96	-	-	Factor A	1.52		0.37	-	-
Factor B	2.11		0.70	-	-	Factor B	1.92		0.64	-	-	Factor B	0.43		0.14	-	-
Factor B at same level of A	N/A	-	0.93	-	-	Factor B at same level of A	N/A	-	1.93	-	-	Factor B at same level of A	0.95	-	0.75	-	-
Factor A at same level of B	N/A	-	1.15	-	-	Factor A at same level of B	N/A	-	1.36	-	-	Factor A at same level of B	1.64	-	0.43	-	-

S1 - 45 x 20 cm, S2 - 60 x 20 cm, S3 -75 x 20 cm; N1 - 120 kg/ha, N2 - 160 kg/ha, N3 - 200 kg/ha, N4 - 240kg/ha, N/A - Not significant

4. DISCUSSION

Little effort has been made to find out such practices against such an important disease in long run. Cultural practices are the economical and sustainable method for disease management as it completely ensures environment safety standards. Following observations were recorded in the present investigation. During the year *Kharif* 2019 and 2020, PDI was significantly influenced by spacing and nitrogen levels. Lowest PDI obtained with the spacing of S3 (75x20 cm) and with the nitrogen level N3 (200 kg/ha). There was also a significant interaction between spacing and nitrogen levels. During the year *Kharif* 2019 and 2020, grain yield was significantly influenced by spacing and nitrogen level both. The maximum grain yield was obtained with the spacing of S3 (75x20 cm) and with the nitrogen level N3 (200 kg/ha). No any significant interactions between spacing and nitrogen levels have been found.

Similar findings reported by Kumar et al. [11] showed that treatment which received high nitrogen fertilizer dosage and closed spacing showed the high significance. The significance showed that interaction between nitrogen fertilizer and spacing. The interaction showed that high percentage disease index (43.8%) was in S1 45x25 cm and N4 240 kg/ ha nitrogen fertilizer. The highest grain yield was obtained with the spacing of S2 (60x25 cm), which was significantly superior to all the spacing. The grain yield (q/ha) was significantly influenced by nitrogen levels. The highest grain yield (54.1q/ha) was obtained with the N1 (120 kg/ha). Bekele [12] also reported that there is a positive correlation between SCLB severity, fertilizer levels and irrigation in maize. Less plant population and poor nutrient management practices are major yield reducing factor in maize suggested by the findings of [13]. Both thicker and thinner plant density than the recommended ones for a normal production system reduces economic yield. Low nutrients supplied may not be sufficient to exploit the genetic potential of maize [14]. Similarly higher tan spot severity in N deficient condition was observed by Fernandez et al. [15].

Similar results were in accordance with the work of W. Bair et al. [16]; Bimla rai et al., 2002; D. Pal and S.A.K.M Kaiser, 2001; Kumar et al. [11].

5. CONCLUSION

In conclusion the results of present study indicated that treatment S3N3 (Spacing 75 x 20 cm, Nitrogen dose 200 kg/ha) were found good with respect to minimize the severity of maydis leaf blight as well as increasing the yield of maize and can be recommended for the management of disease under field conditions. Therefore, this research can have promising potential in agricultural field to protect plants affected with maydis leaf blight thereby increasing yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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