Range Mgmt. & Agroforestry 41 (1) : 81-86, 2020
ISSN 0971-2070

Forage yield compensation in maize with differential seed rates against insect herbivory of *Chilo partellus* (Swinhoe.)

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Received: 8th May, 2019 Accepted: 25th April, 2020

Abstract
The non-pesticidal approach in managing maize stem borer by using differential seed rate (through agronomic manipulations) of fodder maize *vis-a-vis* borer damage and yield compensation study was conducted in 2016 and 2017. The results indicated significant variation in borer inflicted leaf injury (9.84-21.13%), dead heart incidence (6.74-13.25%) and stem tunneling (2.45-6.33 cm) under different sets of plots. The plant damage was, however, significantly low in insecticidal controlled plots. Unlike chemical control, fewer plant losses were recorded in optimally seeded plots (100 kg/ha). The plant losses gradually increased beyond the threshold of optimal limits and could be attributed to modified crop microclimate favouring the *C. patrellus* population buildup and its related damage to foliage and tender shoots. The green fodder yield (q/ha) obtained across different treatment plots was significantly superior on account of high plants population. However, the net returns (Rs. ha^{-1}) indicated the superiority of maize plots seeded @ 100 kg ha^{-1}. This was substantiated by data of leaf injury (15.08%), dead heart incidence (8.41%), stem tunneling (5.9 cm), green fodder yield (422.50 q ha^{-1}) and net returns (Rs. 26837 ha^{-1}) and loss in plant population as compared to other plots with lower or higher seed rates. It was concluded that enhanced seed rate of fodder maize @ 100 kg/ha with no chemical protection against *C. partellus*, had numerical edge for stem borer management, with yield compensation ability and no pesticide usage related issues.

Keywords: *Chilo partellus,* Dead heart, Leaf injury, Seed rate, Stem tunneling, Yield compensation

Introduction

Maize stem borer *Chilo partellus* (Swinhoe.) limits attainable yield potential of fodder maize by infesting the crop in its early growth stages, with a resultant loss in plant stand. The varying attack levels by this lepidopteran pest can be observed throughout the growing season of maize (*Zea mays* Linneaus) in all north Indian agro-ecological zones, seriously projecting it to be the chief limiting factor for fodder maize production (Arabjafari and Jalali, 2007). The incidence of spotted stem borer commences from the first-second week of germination until crop harvest affecting all the above ground plant parts. The losses are in the form of feeding, stem tunneling, dead heart formation and destruction of the growing point thus interference with translocation of metabolites and nutrients leading to under development of the plants, stem breakage, reduced plant vigour, lodging, direct damage to panicles and loss in grain yield (Nyukuri *et al.,* 2014; Prasad *et al.,* 2015). Broad range of insecticides belonging to old and new generation molecules have been recommended for the control of stem borers. But the nature of feeding inside the plant stem gives protection against chemical control and delay in control operations renders the effect of chemical sprays nullified. Considering the consumption of quality fodder maize by dairy animals (Chaudhary *et al*., 2016), it necessitates reliance on non-chemical methods such as manipulations in seed rate with high or optimally seed rate resulting in compensation of the pest attack without appreciable loss in yield and quality. Bragg *et al.* (2016) suggested use of higher seed rate in maize as non chemical pest management strategy. Higher seeding rate of corn had an interactive effect on plant performance which additively benefited plant biomass and seed yield in maize withstanding certain level of insect herbivory (Anonymous, 2017). However, Moyal (1995) recorded infestation of maize stem borer in relation to planting density and suggested that plant damage decreases as plant density decreases and tend to increase under high plant population and other abiotic stress like water deficiency. Keeping this in view, the present investigation was conducted to manage maize stem borer by using differential seed rates (agronomic manipulations), a non-pesticidal approach in fodder maize.

Materials and Methods

***Experimental site and treatments*:** The borer management studies, damage, equivalent green fodder yield and treatments involving variable seed rates and chemical control were conducted on fodder maize variety J1006. The crop was raised following recommended package of practices at Forage Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana during *Kharif* 2016 and 2017. Different levels of seed rate in the present experiment on fodder maize kg ha^{-1} (T_1: 75, T_2: 87.5, T_3: 100, T_4: 112.5, T_5: 125 and T_6: Recommended control of insecticide (coragen 18.5 SC @ 100 ml/ha) with recommended seed rate).

***Observations*:** Damage symptoms like shot holes on leaves and dead hearts (drying of central whorl of leaves) inflicted due to stem borer were recorded in the form of per cent leaf injury and dead heart symptoms at an interval of 7, 14, 21 and 28 days after germination (DAG) in each treatment plots (calculated as: Total number of healthy plants- No. of infested plants showing dead heart symptoms/ Total number of healthy plants × 100). Stem tunneling, and loss in plant population (difference in plant population at germination and harvestable stalk) was recorded at harvest followed by green fodder yield per plot basis and converted to quintal per hectare for economic comparison of different imposed treatments. Other agronomic parameters or yield contributing factors such as plant height (cm), stalk girth (cm), days to 50 per cent flowering and days to ear emergence were also recorded at respective growth stage of the crops at different time intervals.

***Statistical analysis*:** The experimental data was subjected to statistical procedure using analysis of variance for randomized block design and treatments means were separated by least significant difference test (Gomez and Gomez, 1984). The analysis of data was done using computer software CPCS-I (Cheema and Singh, 1991) where per cent leaf injury and dead heart values were transformed into arc sine values before one way analysis of variance (ANOVA).

Results and Discussion

The results as obtained in the present study indicated significant variation in maize stem borer inflicted damage with respect to differential seed rate plots.

Leaf injury incidence (LI): During *Kharif* 2016 and 2017, data recorded on leaf injury at an interval of 7, 14, 21 and 28 days revealed significant differences amongst different plots and insecticide treated plots used as recommended control practice (Table 1). Initially the per cent leaf injury was in range of 3.67-16.33 across all treatments and further aggravated to 11.0-23.83 after 28 days of germination. The overall mean leaf injury across all the observation intervals showed significant difference (9.84-21.13) within plots receiving lower seed amount in comparison to plots receiving higher seed rate (125 kg ha^{-1}). However, the per cent leaf injury was recorded to be significantly lower (6.88) in insecticide treated plots. High plant density resulting from higher seed rate, led to tender foliage resulting in an increased pest attack. The findings of Amudavi *et al*. (2009) also indicated that stalk borer in maize resulted serious losses at early stage of plant growth in high density conditions owing to tenderness of plant stem and foliage. Therefore, plots with high seed rate offered certain degree of potential for diluting the effect of borer damage and compensation in plant population.

***Dead heart (DH) incidence*:** The overall scenario of dead heart (DH) incidence as observed, was low in recommended control practice of chemical control (Table 2), However, the non-chemical pest management strategy consisting of variable seed rates also showed encouraging trends in the form of yield compensation *vis a vis* high seed rate and cost involved for sprays of insecticides. The range of DH percentage was 5.67 to 15.67 across all the observation periods from 7 to 28 days after germination, whereas it was recorded 0.33 to 3.33 per cent in chemically protected plots. On the basis of mean dead heart percentage across all the intervals, the plots with seed rate of 75 kg ha^{-1} showed 6.74 per cent dead hearts, significantly lower than plots sown with 125 kg ha^{-1} seed of fodder maize. However, the 8.92 per cent dead hearts as recorded in plots with 100 kg ha^{-1} were also at par with seed rate of 75 kg ha^{-1}. Van Rensburg *et al*. (1988) suggested that rates of dispersal and the survival of the larvae were enhanced by increased plant population, with a concomitant increase in the number of damaged plants owing to changes in local climate within crop geometry. Walker (1984) also supported increased attack of stalk borer with higher plant density. Matthew and Samantha (2018) advocated high planting density to lower pollen beetle abundance and damage at higher plant densities could occur through dilution effects. Indeed, excess flower numbers (defined as the difference between flower and final pod numbers) produced per plant were strongly negatively affected by increasing plant density, meaning that on a

Table 1. Effect of differential seed rate on *Chilo partellus* inflicted leaf injury percentage (two year pooled data)

Treatments (Seed rate kg/ha)	Per cent leaf injury recorded days after germination 7	14	21	28	Pooled leaf injury (%)
75	6.69(14.96)	9.33(17.71)	10.00(18.35)	13.33(21.37)	9.84(18.12)
87.5	10.67(18.99)	13.67(21.65)	12.33(20.50)	15.33(23.03)	13.00(21.05)
100	12.00(20.22)	14.00(21.95)	16.67(24.05)	17.67(24.81)	15.08(22.78)
112.5	13.67(21.67)	18.00(25.06)	23.00(28.62)	22.67(29.39)	19.33(25.95)
125	16.33(23.80)	19.33(26.05)	25.00(29.96)	23.83(29.17)	21.13(27.26)
Insecticide treatment	3.67(10.98)	5.67(13.71)	7.17(15.48)	11.00(19.33)	6.88(14.91)
CD (P=0.05)	(1.22)	(1.70)	(1.68)	(1.38)	(1.32)

Table 2. Effect of differential seed rate on *Chilo partellus* inflicted dead hearts percentage (two year pooled data)

Treatments (Seed rate kg/ha)	Per cent leaf injury recorded days after germination 7	14	21	28	Pooled dead hearts (%)
75	5.67(13.71)	7.83(16.15)	6.00(14.14)	7.50(15.84)	6.74(14.79)
87.5	6.00(14.10)	8.50(16.91)	6.33(14.53)	7.17(15.41)	7.00(15.25)
100	7.33(15.68)	11.67(19.94)	7.33(15.66)	9.33(17.74)	8.92(17.28)
112.5	9.00(17.40)	14.67(22.47)	8.67(17.05)	11.67(19.95)	11.00(19.25)
125	13.33(21.37)	12.33(20.49)	11.67(19.91)	15.67(23.18)	13.25(21.30)
Insecticide treatment	0.33(1.91)	1.50(6.28)	2.67(9.30)	3.33(10.2)	1.95(7.40)
CD (P=0.05)	(2.19)	(2.25)	(1.49)	(2.32)	(2.37)

Figures in parenthesis are arc sine transformed mean values

per plant basis, beetle susceptibility increased. Therefore, it is evident from present investigation that variation in plant population and plant characteristics are of major significance for pest attack and yield compensation (Walker, 1984; Van Rensburg *et al.,* 1998). However, on the contrary, certain degree of high seed rate proved the plant compensation ability against borer attack and yield of green fodder (Van Rensburg *et al*., 1988).

The stem tunneling length (cm) by larvae of *C. partellus* in treated plots during both the years of study was in range of 4.7-6.23 cm in plots receiving varying seed rates and 2.45 cm in insecticidal controlled plots. The difference of variation in length of feeding tunnel could be attributed to fact of the tender or soft stem in response to marginal plant growth space due to high plant population. Whereas significantly low feeding damage was recorded in insecticide treatment which could be related to toxicity of insecticide against target pest, offering little or no chance to *C. partellus* larvae to bore inside the stalk of plants.

Yield attributes: Yield contributing factors recorded during the present investigation also showed significant effect on plant population. The plant height (cm) recorded across different sets varied from 184 to 235 cm, being lowest in plots receiving seed rate @ 75 kg ha^{-1} and the plant height was maximum in seed plots receiving 100 kg seed ha^{-1} which was significantly superior to other plots as well as insecticide treated plots except the plot seeded with 87.5 kg seed ha^{-1}. Similar pattern was recorded for stem girth (cm), it varied from 1.53 to 1.89 cm being significantly higher in low seed rate plots in comparison to higher seed rate plots. Furthermore, other parameters *viz*., days to 50 per cent flowering and days to ear emergence also showed variations within plots, and ranged from 58 to 62.66 and 65 to 71.6 days respectively, across different treatment plots (Table 3). The average green fodder yield (GFY; q/ha) obtained over two years of study period showed the same trend of higher yield in plots with higher seed rate in comparison to low seed rate as well as insecticide treated plots. There was yield advantage of 6 to 33.93 q/ha (Fig 1) in plots seeded with higher seed rate as compared to plots with low seed rate (75 kg ha^{-1}). However, the realization of GFY (422.50 q/ha) as obtained in plots with seed rate of 100 kg ha^{-1} was at par with plots receiving enhanced seed amount as well as chemically treated plots (423.17 q/ha) owing to high number of harvestable canes as evident from loss of plant population in different of plots (Fig 2). Hence, these variable factors responsible for differences in production potential were expected to contribute substantially to differences in the damaging capacity of *C. partellus.* These findings were in line with the work of Walker (1960) who provided separate loss functions in terms of plant characteristics and yield components for *B. fusca* in high and low densities maize plantings. Moyal (1995) suggested number of factors that affected the insect-plant interaction owing to varying plant densities affecting the borer damage and subsequent yield potential of the maize crop in irrigated and water stress fields. Bastos *et al.* (2020) propounded that producer might select different seeding rates and genotypes of winter wheat with varying levels of tillering potentials for risk aversion. Either increasing seeding rates or selecting high tillering potential genotypes could be used to decrease weather-related production risk. However, the former might not be the most economical practice if adverse weather did not happen and a lower seeding rate might produce equally well.

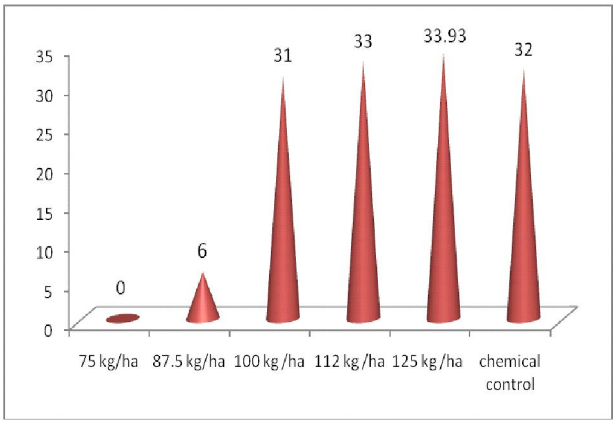

Fig 1. Yield advantage (q/ha) across different seed rate plots and chemically managed plot

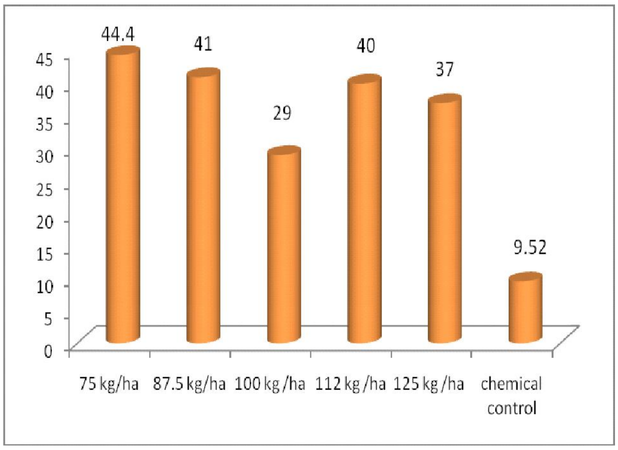

Fig 2. Per cent loss in plant population at harvest in different set of plots

Economic analysis: The economic analysis of different treatments and subsequent GFY revealed net return ranged between Rs. 23607 to 27227 ha^{-1}. In the present study the maximum net return (Rs. 27227 ha^{-1}) was realized in plots with insecticide treatment for borer management. However, amongst differential seed rate plots, net return of Rs.26837 ha^{-1} was obtained in plots seeded with 100 kg ha^{-1} seed rate which was marginally low from insecticide control. The treatments plots receiving maximum seed rate (125 kg ha^{-1}) though yielded highest GFY but incurred additional seed cost and high

Table 3. Agronomic parameters as affected by varying seed rate

Treatments (Seed rate kg/ha)	Plant height (cm)	Stem girth (cm)	Days to 50% flowering	Days to ear emergence	GFY-2016 (q/ha)	GFY-2017 (q/ha)
75	184	1.60	60.33	66.66	389.33	393.00
87.5	232	1.76	58.00	65.00	401.00	393.33
100	235	1.71	60.66	68.33	421.33	423.67
112.5	218	1.63	59.00	68.66	427.00	422.33
125	201	1.53	60.66	71.60	427.00	423.00
Insecticide treatment	186	1.79	62.66	68.00	425.00	421.00
CD (P=0.05)	5.16	0.14	2.09	1.04	10.18	8.06

Figures in parenthesis are square root ($\sqrt{n+1}$) transformed mean values

Table 4. Economic analysis of varying seed rate plots and net return obtained over two years study

Treatments (Seed rate kg/ha)	*Leaf injury (%)	*Dead hearts (%)	GFY (q/ha)	**Stem tunneling (cm)	Net return (Rs./ha)
75	9.84(18.12)	6.74(14.79)	391.17	4.7(2.38)	23607
87.5	13.00(21.05)	7.00(15.25)	397.17	5.03(2.45)	23918
100	15.08(22.78)	8.92(17.28)	422.50	5.9(2.62)	26837
112.5	19.33(25.95)	11.00(19.25)	424.67	6.33(2.68)	26630
125	21.13(27.26)	13.25(21.30)	425.10	6.23(2.68)	26188
Insecticide treatment	6.88(14.91)	1.95(7.40)	423.17	2.45(1.27)	26742
CD (P=0.05)	(1.32)	(2.37)	6.43	(0.12)	-

**Figures in parenthesis are square root ($\sqrt{n+1}$) transformed mean values; *Figures in parenthesis are arc sine transformed mean values; Cost of seed Rs. 40/kg; Cost of insecticide spray Rs. 1500/ha; Green fodder Rs. 135/q pest attack resulted in marginal downfall in net returns. Whereas net return (Rs./ha) recorded in plots seeded with 100 kg ha^{-1} was also comparable. Elomre and Abendroth (2008) demonstrated increased herbivory by stem borer in corn due to higher plant population but certain degree of higher plant stand additively affected plant biomass and seed yield without any appreciable effect on plant performance. Judith and Sarfraz (2017) suggested insect-feeding damage kills plants, but more often, it reduces plant size, growth, and seed production. Plant populations for which seed germination is site limited will not respond at the population level to reduced seed production. Alterations due to climate change within cropping ecosystem influence the distributions of insect-pests. It was observed that optimum seed rate led to yield advantage of 31 q/ha green fodder, though maximum green fodder yield was in plots, seeded with 112.5 and 125 kg/ha of seeds (Fig 1). But the economic analysis of these plots indicated net economic returns were maximum in plots with high seed rate of 100 kg/ha. This was further supported by the fact that amongst varying seed rate plots, minimum loss in plant population (29%) was observed in promising seed rate of 100 kg per hactare plots as against 37 to 44% losses as observed in varying seed rate plots and receiving no chemical intervention.

Conclusion

Keeping in view the availability of quality green fodder, safety of dairy animals and pesticide abuse, it was concluded that fodder maize sown with higher seed rate of 100 kg ha^{-1} as against recommended seed rate of 75 kg ha^{-1}, was economical in comparison to lower seed rate plots as well as beyond optimum seed rate plots. This was further supported by higher net returns with yield advantage and high number of harvestable stalks. Hence, it could serve as a non-chemical strategy to thwart the attack of maize stem borer in-terms of compensation of plant strand due to high seed rate.

Acknowledgement

The authors are thankful to All India Coordinated Research Project on Forage Crops and Utilization for providing necessary guidance and financial support for conducting the investigation.

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