Management of snout beetles (Coleoptera: Curculionidae) on maize using Dynamic 400 FS in north-western Ethiopia

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ABSTRACT

Despite the huge role maize plays as a staple food crop in Ethiopia, soil dwelling snout beetles, among other constraints, are upsetting its production. The pests have created an emergency management situation in north-western Amhara, Ethiopia. To alleviate this constraint, the insecticide Dynamic, along with the standard insecticide (check), Cruiser and others, was evaluated in the field against snout beetles in 2010. The experiment was laid out in randomized complete block design with three replications. The highest rate of 'Dynamic (4 ml/kg seed)' performed close to the standard check, Cruiser, in terms of maize stand count, maize seedling damage, snout beetle population and grain yield. Mean grain yield levels ranged from 2270 kg/ha for the untreated check to 4600 kg/ha for plots treated with the highest rate of Cruiser (3 ml/kg seed). Higher rate of Cruiser application gave the highest grain yield advantage, i.e., 103% (or 2330 kg/ha) over the untreated control. The second highest yield advantage (90% or 2050 kg/ha) over the control was obtained from the highest rate of Dynamic application (4 ml/kg seed). Therefore, Dynamic is recommended for immediate application at the higher rate of 4 ml/kg seed against snout beetles.

Keywords: Yield, Maize, Dynamic, Snout beetles, Management
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INTRODUCTION

Maize (*Zea mays*) is an important crop and the most staple food in Ethiopia. However, biotic and abiotic factors become growing concern on maize

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yield. Among the biotic factors, insect pests and disease damage to maize production is of paramount important. Soil insects can be particularly damaging to maize crop because they reduce plant density. Snout beetles and termites are among the most important soil dwelling insect pests (Abraham Tadesse, 2008). Of which, *Diaecoderus* sp., *Systates exaptus, Tanymecus destructor, Mesoleurus dentipes* and *Protostrophus* spp. are some common snout beetle species recorded in different countries.

Since 2000s, snout beetles have steadily increased their presence and damage in the major maize growing areas of western Amhara regional state, Ethiopia. Farmers reported that snout beetles damage is severe on maize plants grown next to finger millet fields. Fallows are also a source of snout beetle infestation (Sileshi Gudeta and Mafongoya, 2003). Severe snout beetle infestation at seedling stage results in poor stand count and complete death of the plant and eventually low grain yield. Although experts and farmers generally consider snout beetles important, there is no detailed information in the area about the status of these pests, the damage they cause and the yield loss that can be inflicted. These pests have created an emergency situation.

Different management methods have been investigated against snout beetles in different parts of the world. Although cultural and biological methods of pest control are generally regarded as more sustainable and appropriate, in practice pest management relied heavily on synthetic pesticides for decades. Pesticides offer immediate solution to the problem, which are usually effective, because of the rapid knockdown effect, at least in the short-run. Instead of relying on one or a few magic bullets against pests, it is always preferable to have at our disposal a range of pest management tools including commercial pesticides, as a component of integrated pest management. There is a dire need of regularly evaluating the efficacy of available chemicals to provide effective management options. Given the extent of the problem in the current study area, other more environment friendly options such as cultural practices are ideal; however, once the problem happens, pesticides are required to prevent further damage. Cruiser 350 FS (common name: thiamethoxam 35% FS) is registered for the control of Russian wheat aphid on barley. At present, Diazinon pesticide is used against some maize pests including snout beetles (Pers. obs.). Dynamic 400 FS (common name: Thiram + Carbofuran) was introduced in Ethiopia through Lions International Trading P.L.C for test. Therefore, Dynamic 400 FS was evaluated along with Diazinon and

Cruiser against snout beetles for the first time in the area on maize for immediate recommendation and application. The study was also intended to shed light on the economic importance of these beetles, the damage they cause, and the yield loss they inflict on maize.

MATERIALS AND METHODS

Description of study area

Mecha and Achefer are two of the districts in West Amhara region of Ethiopia, a region considered to be one of the few grain sources of the country. The study areas belong to Ethiopia's Agro-ecological zone classified as "tepid to cool sub-moist mid-highlands" (Temesgen Tadesse, 2007). Specific sites in each district were Merawi in Mecha and Yismala in Achefer.

The first study district, i.e., Mecha is situated at an altitude of 1800 to 2500 m above sea level and has an area of 156 thousand hectares (Habtamu Addis, 2012). It receives an average annual rainfall of 1000 to 2000 mm and an average daily temperature of 24 to 27°C. Some 80% of the area is temperate and the remaining 20% is moderately temperate. In 2007, the population of Mecha was 336,697 in rural and 27,637 in urban areas (CSA, 2008). About 92% of its economy is dependent on agriculture. The main products are; maize, teff (*Eragrostis tef* (Zucc.)), Trotter and finger millets. The most dominant soil type, the Nitisols cover 92% of the area, and the remaining soils are Vertisols and Vertic Nitisols. Seventy five percent of the study area is gently sloping, 13% is moderately sloping and 8% mountainous while 4% consists of valleys (Habtamu Addis, 2012).

The other location where the study was carried out was Achefer. The altitude of Achefer ranges from 1,500 to 2,500 m above sea level. The mean annual rainfall ranges from 1,450 to 1,594 mm. About 87% enjoys temperate climate and the remaining 13% has cold climatic conditions. According to the Amhara Regional State Bureau of Finance and Economic Development 2011 population prediction, the total population was about 148,974; a population density of 1.24/ha, and 90.2% of which resides in rural areas. According to the district agriculture office sources, the total geographical area of Achefer is about 118,228 ha. The topography is generally flat with some hills, valleys and undulating areas (Molla *et al.*, 2014). Some 50% of the soils are red, 40% brown and the rest are mixtures. Each household practices mixed farming with minimal modern technology. The main crops grown include maize, teff, finger millet, wheat, chickpea, beans, niger seed, and cabbage. It is one of the food-secured districts in the country.

Treatments and experimental design

This experiment was carried out in 2010/11 cropping season in Mecha and North Achefer, western Amhara, Ethiopia, where the pest has become economically important on maize seedlings. The treatments, Dynamic 400 FS (Thiram 20% + Carbofuran 20% FS) at three different rates, i.e., 2, 3, 4 ml/kg of seed were evaluated together with Cruiser 350 FS (Thiamethoxam 35% FS) @ 3 ml/kg of seed, Diazinon 60% EC @ 1 l/ha and untreated control.

The field experiment was laid out in a randomized complete block design with three replications. Dynamic and Cruiser were used as seed dressing after diluting with water to ensure effective seed coverage during application, while Diazinon was used as a foliar spray at maize seedling emergence. The plot size was 4 m × 4.5 m (18 m^2). Spacing between rows was 75 cm and between plants 30 cm. Fertilizer application and other agronomic practices were done as per the latest research recommendation.

Data collection and analysis

Maize plant stand count, number of damaged seedlings, number of snout beetles and grain yield were recorded per plot basis. Statistical analysis was performed using the Statistical Analysis Systems (SAS version 9) software (SAS, 2008). Shapiro-Wilk test was performed to check the normality assumption by conducting a series of tests for each variable with respect to individual treatments and locations. No severe violation of normality was observed. Also, homogeneity of variance assumption was not violated according to the results of the Levene's test. All data were then subjected to factorial analysis of variance (ANOVA) by taking treatments (pesticide applications), crop growth stages and locations as factors (sources of variation). Treatment means were separated by using Tukey Honestly significance difference test at p=0.05. Yield advantage of the treatments over the untreated check was calculated by subtracting the mean yield of the check from means of each treatment. Also, Pearson's correlation analysis was performed between some plant growth parameters, beetle populations, damage levels and grain yields.

RESULTS

The application of seed dressing chemicals drastically reduced snout beetle numbers and their damage and improved the performance of maize plants in terms of stand count and grain yield.

Maize stand count

Stand count at emergence did not significantly vary among treatments at both locations. However, it tended to increase with increasing rate of Dynamic application at both locations (Table 1). Stand count was generally higher at Mecha, which varied between a mean of 26 from untreated plots to a mean of 45 on Cruiser treated plots. Stand count was also lower at harvest than at emergence. The chemicals, i.e., seed dressings, enhanced the emergence of maize seedlings. They gave better stand count than Diazinon aerial spray and the untreated control.

Population of snout beetles

Snout beetle numbers significantly varied between the different factors such as locations, type and rate of pesticide application, time of sampling and their interactions ($F_{35,72}$=171.25, $P<0.0001$). Regardless of location, numbers generally tended to be more at Mecha than at Achefer and at the time of crop emergence than at two weeks and four weeks after emergence (Table 2). Therefore, numbers steadily declined from the highest number at emergence to the lowest at four weeks after emergence. They were not found after four weeks indicating that their feeding guild is the seedling stage. At Mecha, two weeks after emergence, the different rates of Dynamic and Cruiser significantly reduced snout beetle numbers compared with Diazinon and untreated check. More or less the same pattern was observed at Achefer. The effect of the treatments on beetles was more evident at two weeks after emergence than at the time of emergence and one month later. The lowest number of snout beetles was recorded on the plots treated with Dynamic at 4 ml/kg of seed followed by Cruiser at the time of emergence. There was no significant difference of snout beetle count among seed dressing chemicals after two weeks of emergence (Table 2). Application of Diazinon at the time of crop emergence could not control the beetle as satisfactorily as other chemicals.

Table 1. Effect of different rates of Dynamic 400 application on maize stand count at Mecha and Achefer, northwestern Ethiopia.

Treatments	Emergence	Harvest
Mecha		
Untreated check	44.33a-e	26.33h
Diazinon aerial spray @ 1 l/ha	45.00a-e	30.33f-h
Dynamic seed treatment @ 2 ml/kg seed	48.00a-c	39.33b-f
Dynamic seed treatment @ 3 ml/kg seed	48.33ab	44.33a-e
Dynamic seed treatment @ 4 ml/kg seed	49.33a	44.67a-e
Cruiser seed treatment @ 3 ml/kg seed	49.00a	45.33a-d
Achefer		
Untreated check	45.33a-d	28.67gh
Diazinon aerial spray @ 1 l/ha	47.00a-c	30.00f-h
Dynamic seed treatment @ 2 ml/kg seed	47.00a-c	35.67e-h
Dynamic seed treatment @ 3 ml/kg seed	47.00a-c	37.00d-g
Dynamic seed treatment @ 4 ml/kg seed	46.33a-d	39.00b-f
Cruiser seed treatment @ 3 ml/kg seed	47.33a-c	38.67c-f

Means followed by the same letter(s) is(are) not significantly different according to Tukey Honestly Significant difference test at α=0.05; lettering example: a-e stands for all English letters (alphabets) from “a” to “e”, c-f for letters c to f, etc. Each mean was calculated from three replications.

Seedling damage

Application of seed dressing chemicals effectively reduced infestation of snout beetles on maize seedlings in treated plots over untreated plots at both locations (Table 3). The critical time of snout beetle damage or high damage was observed at two weeks after crop emergence. Damage at one month after crop emergence was negligible. Taking two weeks after emergence as a reference time, damage caused by snout beetles varied with location (Table 3). More damage was observed at Mecha than at Achefer. At Mecha, higher rates of Dynamic and Cruiser had significantly lowered damage levels than Diazinon and the untreated check. Treatments did not vary in the level of damage at Achefer. Therefore, the results showed that the use of seed dressing chemicals protects maize plants from snout beetles better than the other treatments. The lowest damage was observed on

Cruiser and Dynamic @ 4 ml/kg. Beetles were more active at the seedling stage (Table 2).

Table 2. Effect of different rates of Dynamic 400 application on the number of snout beetles at Mecha and Achefer, northwestern Ethiopia.

	At emergence	Two weeks after emergence	One month after emergence
Mecha			
Untreated check	23.00a	22.00ab	8.00g-l
Diazinon @ 1 l/ha spray	22.33a	17.67a-f	6.33h-l
Dynamic @ 2 ml/kg seed	20.67a-c	10.67d-k	4.00i-l
Dynamic @ 3 ml/kg seed	20.67a-c	8.67e-l	1.67j-l
Dynamic @ 4 ml/kg seed	17.00a-g	7.00h-l	1.67j-l
Cruiser @ 3 ml/ kg seed	18.00a-e	8.33f-l	1.33kl
Achefer			
Untreated check	19.67a-d	15.00a-h	0.01l
Diazinon @ 1 l/ha spray	17.67a-f	10.33d-k	0.01l
Dynamic @ 2 ml/kg seed	12.33c-i	12.33c-i	0.01l
Dynamic @ 3 ml/kg seed	12.67b-i	6.33h-l	0.01l
Dynamic @ 4 ml/kg seed	11.33c-i	5.33i-l	0.01l
Cruiser @ 3 ml/ kg seed	11.00d-j	5.67h-l	0.01l

Means followed by the same letter(s) is(are) not significantly different according to Tukey Honestly Significant difference test at α=0.05. Each mean was calculated from three replications.

Plant height at harvest

Plant height did not vary among treatments and locations ($F_{11,24}$=0.9, P=0.5521). However, the mean range in plant height varied between 186.4 cm at Achefer on Diazinon treated plants to 200 cm at Mecha on plants treated with Dynamic @ 4 ml/kg seed. Therefore, at Mecha, an increasing tendency of plant height was observed (Figure 1).

Grain yield

Grain yield per plot significantly varied between locations, treatments and their interaction ($F_{11,24}$=153.122, P<0.0001). The final harvested grain yield from plots treated with seed dressing chemicals was significantly higher than untreated control as well as from Diazinon sprayed plots at both locations. Yield appeared to be higher at Mecha than at Achefer. Increasing rate of pesticide application gave increasing amount of yield (Figure 2). Untreated check and Diazinon treatments gave slightly higher yield at Achefer than at Merawi. Cruiser and Dynamic performed best at Merawi.

Table 3. Effect of different rates of Dynamic 400 application on maize seedling damage at Mecha and Achefer, northwestern Ethiopia

	At emergence	Two weeks after emergence	One month after emergence
Mecha			
Untreated check	5.67a-f	10.67a	1.67ef
Diazinon @ 1 l/ha spray	4.67a-f	9.33a-c	0.67ef
Dynamic @ 2 ml/kg seed	2.00d-f	6.33a-f	0.33ef
Dynamic @ 3 ml/kg seed	2.33ef	3.67 b-f	0.00f
Dynamic @ 4 ml/kg seed	1.00ef	3.67 b-f	0.00f
Cruiser @ 3 ml/ kg seed	1.00ef	2.67d-f	0.00f
Achefer			
Untreated check	6,67a-e	10.00ab	0.0f
Diazinon @ 1 l/ha spray	8.33a-d	4.33a-f	0.0f
Dynamic @ 2 ml/kg seed	5.67a-f	4.33a-f	0.0f
Dynamic @ 3 ml/kg seed	3.33c-f	6.00a-f	0.0f
Dynamic @ 4 ml/kg seed	3.00c-f	4.33a-f	0.0f
Cruiser @ 3 ml/ kg seed	3.67 b-f	4.67a-f	0.0f

Means followed by the same letter(s) is(are) not significantly different according to Tukey Honestly Significant difference test at α=0.05. Each mean was calculated from three replications.

Grain yield advantage

All pesticide treatments gave more yield than the untreated check. Percent yield advantage due to pesticide use varied between locations and between treatments (Figure 3). The maximum advantage, however, was obtained at Mecha, which was nearly 3-fold as much as the yield advantage from Achefer. At Mecha, compared to the untreated control, the yield advantage of using pesticides ranged from 15% (Diazinon treated plots) to 103% (Cruiser treated plots). Therefore, Cruiser gave the highest yield advantage, i.e., 2330 kg/ha. Dynamic gave more yield than the untreated control that varied between 61% at 2 ml/kg seed treatment and 90% at 4 ml/kg seed treatment. It gave between 1390 kg and 2050 kg/ha more yield than the untreated control. The yield advantage of Dynamic steadily increased with increasing rate of application, i.e., 2 ml/kg to 4 ml/kg.

At Achefer, the yield advantage ranged from 14.5% (370 kg/ha) by using diazinon to 42.5% (1070 kg/ha) by using Cruiser. The performance of diazinon appeared to be independent of location because the trivial increase at Achefer, the yield advantage was by and large the same at both locations. The lowest advantage over the control was obtained from plants treated with diazinon.

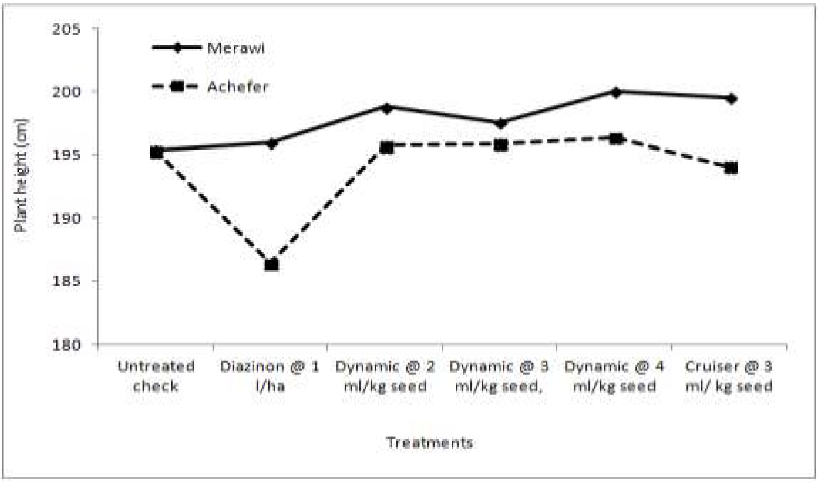

Figure 1. Plant height (cm) and pesticide treatments Mecha and Achefer districts of Amhara Regional Sate, Northwest Ethiopia

Correlation coefficients between different variables

Generally, correlations were similar at the two locations. Beetle count and the damage they inflicted had a consistent positive correlation. On the other hand, both had negative correlation with plant growth parameters such as stand count, plant height and grain yield. At Achefer, stand count at harvest showed significant negative correlation with snout beetle populations and the damage they caused and positive correlation with grain yield (Table 4).

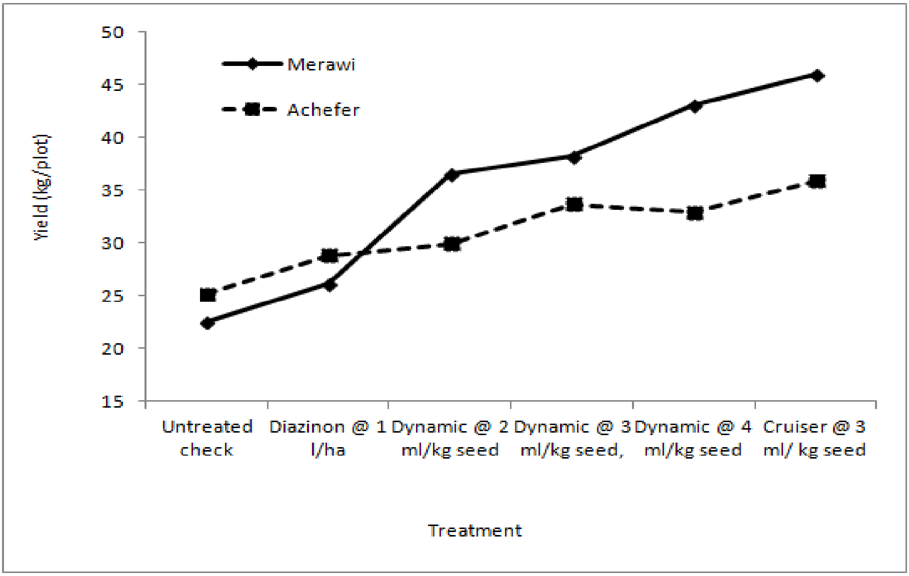

Figure 2. Grain yield (kg/plot) and pesticide treatments Mecha and Achefer districts of Amhara Regional Sate, Northwest Ethiopia

More stand count at harvest implies more yield. Number of damaged plants at emergence was also positively correlated with number of snout beetle population but negatively with yield. Snout beetle numbers both at emergence and two weeks after crop emergence were negatively correlated with yield.

Similarly, at Mecha, stand count at harvest was strongly negatively correlated with beetle counts and damage levels (Table 5). It was correlated positively with yield. Damaged plants and beetle populations were positively correlated. Plant height was negatively correlated with beetle numbers the damage they caused. Yield was negatively correlated with damage and beetle numbers but positively with stand count and plant height

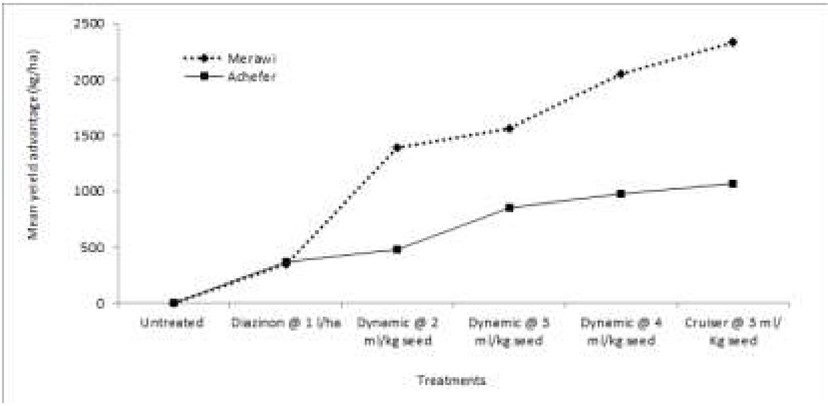

Figure 3. Percent yield advantage obtained over the untreated control by using different pesticides at different rates of application at Mecha and Achefer districts of Amhara Regional Sate, Northwest Ethiopia.

DISCUSSION

The damage caused by snout beetles on maize is explained in terms of reduction in plant stand count and grain yield. Adults and grubs of snout beetles feed on maize stems and roots, weakening or killing seedlings and causing plant density to decline with time (Van Dyn, 2004). Dynamic 400 FS and Cruiser were effective in reducing loss of stand and yield. Based on the result from the current research, Dynamic 400 FS (Thiram + Carbofuran) is registered in Ethiopia for the control of snout beetles on maize (to be used as seed treatment pesticide) (MoA, 2013). The current research underpinned the efficacy of Dynamic 400 FS for snout beetle management. Pesticide treatment also reduced snout beetle population significantly. Effectiveness increased with increasing rate of application. Therefore, pesticides could be used to stop an emergency condition, i.e., an infestation that is too late for other options to be effective. However, future research and development efforts should also incorporate other options that are more environments friendly. Because farmers in the study area believe that these beetles are more common in maize fields that border finger millets, there is a need to keep nearby fields clean of volunteer plants and grasses. Fallows serve as sources of snout beetle infestation (Sileshi Gudeta and Mafongoya, 2003). Snout beetles are more numerous in no-till systems (Alabama A&M University & Auburn University, 2016). Economic damage is severe in maize fields grown without rotation, or grown adjacent to the previous year's maize field, or in fields seriously infested with grasses. Rotation is, therefore, an effective management tool for these beetles because the insect has only one generation per year, moves by crawling, and has a limited host range (Alabama A&M University & Auburn University 2016). Rotation is particularly effective when large fields are rotated, increasing the chances of isolation. Keeping good nutrient balance and irrigation can increase the tolerance of the plant to the beetles. In addition to the pesticide, these otherwise environmentally friendly options need to be investigated in greater detail. These techniques may give comparable results to pesticide use.

Pesticide seed treatment also significantly reduced maize seedling damage. The beetles were most active at the seedling stage. Snout beetles, also called billbugs, cause damage from emergence through 6 to 8 leaf growth stages of maize and adult beetles and grubs feed on maize stems and roots, weakening or killing seedlings (Alabama A&M University & Auburn University 2016). In the current study, snout beetles were effectively controlled by the chemicals Cruiser and Dynamic seed dressing. Seed-applied or banded insecticides can help limit snout beetle damage to maize (Purdue Extension Entomology, 2009). Grain yield was significantly increased by using pesticides.

CONCLUSION

Because of the emergency situation created by snout beetles on maize, immediate solutions were expected soon after the outbreaks. Recently snout beetles have become the most dangerous soil pest of maize plants in Mecha and North Achefer, northwestern Ethiopia. Chemical seed dressing gave satisfactory protection of maize against this pest. Chemical seed dressing replaces foliar sprayed insecticides, which contributed to environmental pollution and the destruction of beneficial fauna (predators and honey bees). Dynamic 400 FS protected the maize crop nearly as effectively as the standard product, Cruiser 350 FS. Dynamic 400 FS is easy to apply and is safe to non-target organisms than older alternatives. Farmers, who do not have access to Cruiser 350 FS due to high cost and limited market supply, could afford Dynamic 400 FS.

Table 4. Correlation analysis between different plant growth parameters, beetle numbers, damage levels and grain yield at Achefer.

	SCE	SCH	DPE	DP2WAE	SBCE	SBC2WAE	PH	GY
Stand count at emergence (SCE)	1							
Stand count at harvest (SCH)	0.2	1						
Damaged plants at emergence (DPE)	0.1	-0.7**	1					
Damaged plants at 2 weeks after emergence (DP2WAE)	0.1	-0.6**	0.3	1				
Snout beetles at emergence (SBCE)	-0.1	-0.6**	0.6**	0.3	1			
Snout beetles at 2 weeks after emergence (SBC2WAE)	-0.3	-0.4	0.5*	0.1	0.7**	1		
Plant height (PH)	-0.2	0.3	-0.3	0.3	-0.3	-0.3	1	
Grain yield (GY)	0.2	0.5*	-0.4	-0.2	-0.6**	-0.5*	0.1	1

Table 5. Correlation analysis between different plant growth parameters, beetle numbers, damage levels and grain yield at Mecha.

	SCE	SCH	DPE	DP2 WAE	SBCE	SBC2 WAE	SBC4 WAE	PH	GY
Stand cunt at emergence (SCE)	1								
Stand count at harvest (SCH)	0.9**	1							
Damaged plants at emergence (DPE)	-0.7**	-0.9**	1						
Damaged plants at 2 weeks after emergence (DP2WAE)	-0.7*	-0.9**	0.8**	1					
Snout beetles at emergence (SBCE)	-0.3	-0.6**	0.7**	0.7**	1				
Snout beetles at 2 weeks after emergence (SBC2WAE)	-0.8**	-0.8**	0.8**	0.7**	0.5*	1			
Snout beetles at 4 weeks after emergence (SBC4WAE)	-0.7**	-0.8**	0.8**	0.7**	0.5	0.7**	1		
Plant height (PH)	0.3	0.4	-0.3	-0.4	-0.4	-0.2	-0.2**	1	
Grain yield (GY)	0.8**	0.8**	-0.8**	-0.8**	-0.6*	-0.9**	-0.8**	0.4	1

Based on the result, we recommended the highest rate (4 ml/kg seed) of Dynamic 400 FS for soil dwelling insect pests. Dynamic 400 FS can replace Cruiser 350 FS, which is also good but not available in the local market. However, chemicals must be options at the last resort and in such emergency situations. Some cultural practices are said to be as effective and future research efforts should target these alternatives.

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