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Short Communication

Popping quality attributes of popcorn hybrids in relation to weevil (*Sitophilus oryzae*) infestation

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Abstract

A set of 21 popcorn hybrids were evaluated at multi-locations to study the effects of weevil (*Sitophilus oryzae*) infestation on popping quality traits. Wide genetic variation for percent popping expansion (PPE) and grain popping percentage (GPP) after weevil infestation were observed. PPE and GPP varied from 6.09-85.21% and 4.33-66.67%, across locations, respectively. The mean PPE was 52.90%, while same for GPP was 23.46%. Significant effects of environment and genotype × environment interactions were observed for both PPE and GPP. Strong positive correlation (r=0.89) across locations was recorded between PPE and GPP. Despite weevil infestation, popcorn hybrids *viz.,* PH114 (PPE: 83.18%, GPP: 54.11%), PH110 (PPE: 69.27%, GPP: 33.11%), PH103 (PPE: 65.84%, GPP: 26.78%), PH112 (PPE: 64.91%, GPP: 29.22%) and PH109 (PPE: 64.48%, GPP: 29.00%) were identified as promising with desirable popping quality traits. Many of the popcorn hybrids possessed undesirable popping characteristics (12 hybrids with <60% PPE; 18 hybrids with <30% GPP) upon infestation. Despite having a common notion that popcorn genotypes are relatively resistant than other types of maize grain, many of the popcorn hybrids were highly susceptible to weevils leading to undesirable popping quality attributes. The study emphasizes the need for breeding weevil resistant popcorn genotypes possessing desirable popping quality attributes.

Key words: Popcorn, popping, *Sitophilus oryzae*, variability, maize

Popcorn has emerged as one of the most popular snacks worldwide, production of which has been steadily increasing for decades (Soni and Khanorkar 2014). Grains of popcorn genotypes are small in size having hard and more corneous fraction of endosperm (Zeigler 2001). Popcorn flakes are prepared by heating grains at high temperature (180-190°C). The water inside is converted into both steam and superheated water, which led to the rupture of pericarp coupled with rapid expansion of molten starch resulting in fluffy and edible flakes (Hoseney et al. 1983). High popping expansion and higher number of popped grains are of utmost importance to popcorn consumers (Babu et al. 2006). Among various methods, microwave popping is popular as it is more efficient than the traditional heating processes with benefits of quicker start-up time, energy efficiency and final products with improved nutritive quality (Jele et al. 2014).

Among various storage grain insect-pests, *Sitophilus oryzae* causes substantial damage to the maize grains, especially in the Asian countries. Grain weight loss of 12-20% is common due to weevil infestation, and it may reach up to 80% under favourable conditions (Tefera et al. 2013). In the developing world, maize grains are stored in gunny bags, which during rainy season absorb moisture and result in conducive conditions for the weevil infestation (Hossain et al. 2007; Zunjare et al. 2014). Weevils not only affect popcorn structure and composition, but also

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allow pathogens such as *Aspergillus flavus* and *Fusarium verticillioides* to produce carcinogenic mycotoxins on the surface of the grains (Dowd and Johnson 2010). Thus, evaluation of popcorn hybrids for their responses to popping quality attributes in relation to weevil infestation holds immense significance (Jele et al. 2014). To best of our knowledge, no study has been reported on responses of popping quality traits among popcorn hybrids upon *S. oryzae* infestation. Hence, the present study was aimed to evaluate genetic variability for popping quality attributes among selected popcorn hybrids and to identify promising hybrids with desirable popping characteristics upon infestation by *S. oryzae*.

Twenty one popcorn hybrids (PH101 to PH121) generated by crossing seven popcorn inbreds (in all possible combinations without reciprocals), were evaluated at three locations *viz*., IARI, New Delhi; GBPUAT, Pantnagar and CSK-HPKV, Bajaura during *kharif* 2011. Genotypes were planted in a randomized complete block design with two replications per entry and one row per replication, with a plant-to-plant spacing of 25 cm and row-to-row spacing of 75 cm. Three plants in each of the replication were hand pollinated to avoid any xenia effects. Hundred self-fertilized grains of popcorn hybrids in each of the replication were evaluated for their responses to *S. oryzae* infestation, as per the procedure described by Hossain et al. (2007) and Zunjare et al. (2014). After infestation experiment, grains were cleaned for analyses of popping quality traits. The grains were popped in a microwave (Model: LG grill intellowave, MH6558F, India) for two minutes (Babu et al. 2006). The volume (ml) of kernels before and after popping was measured using a 250 ml measuring cylinder, and expressed as percent popping expansion (PPE) calculated as [{(volume after popping – volume before popping)/volume before popping} x 100]. The number of popped grains was counted and expressed as grain popping percentage (GPP). The data sets from three locations were analyzed for ANOVA using WINDOSTAT 8.5, and Pearson's simple correlation between PPE and GPP was computed using MS Office-Excel 2007.

ANOVA revealed significant variation for PPE and GPP among popcorn hybrids in all the three locations (Table 1). Pooled analyses also showed wide variation for both the traits across environments (Table 2). PPE ranged from 21.14-85.02%, 23.78-79.32% and 6.09-85.21% at Delhi, Pantnagar and Bajaura, respectively. GPP also showed wide variation at all three locations (Delhi: 4.33-55.67%, Pantnagar: 5.33-40.00%, Bajaura: 4.67-66.67%). This indicates the presence of ample genetic variation amenable to improvement of popping quality traits among popcorn hybrids upon weevil infestation. PPE and GPP showed strong positive correlation between them across locations (Delhi: r = 0.91, Pantnagar: r = 0.84, Bajaura: r = 0.77, pooled: r = 0.89). This relationship is in congruence with earlier reports where non-infested grains were used for evaluating popping quality parameters (Babu et al. 2006; Jele et al. 2014).

Table 2. Combined ANOVA for popping quality attributes of popcorn hybrids

Source of variation	df	MSS	
		PPE	GPP
Genotypes	20	1273.46**	689.80**
Environment	2	2864.50**	389.95*
Genotypes x Environment	40	828.30**	414.30**
Error	126	137.84	106.15
Total	188	434.56	236.83

df: degrees of freedom; MSS: Mean sum of squares; PPE: Percent popping expansion; GPP: Grain popping percentage; *, **Significant at *P*=0.05 and 0.01, respectively

Table 1. ANOVA for popping quality attributes of popcorn hybrids

Source of variation	df	MSS					
		PPE			GPP		
		Delhi	Pantnagar	Bajaura	Delhi	Pantnagar	Bajaura
Genotype	20	1619.96**	744.55**	737.16**	833.45**	269.26**	269.26*
Replication	2	117.61	249.15	350.24	431.69*	69.45	168.78
Error	40	85.72	142.39	170.23	133.42	51.62	115.85
Total	62	581.67	340.08	358.91	368.85	122.4	167.04

df: degrees of freedom; MSS: mean sum of squares; PPE: Percent popping expansion; GPP: Grain popping percentage; *,**Significant at P = 0.05 and 0.01, respectively

Popcorn genotypes are generally regarded as resistant to weevil infestation compared to normal maize. Zunjare et al. (2014) reported the inherent nature of resistance among popcorn inbreds as compared to sugary- and shrunken-sweet corn, and quality protein maize (QPM) inbreds. Among the hybrids, PH114 (PPE: 83.18%, GPP: 54.11%), PH110 (PPE: 69.27%, GPP: 33.11%), PH103 (PPE: 65.84%, GPP: 26.78%), PH112 (PPE: 64.91%, GPP: 29.22%) and PH109 (PPE: 64.48%, GPP: 29.00%) were promising across locations despite having weevil infestation. These hybrids thus possessed higher degree of resistance against *S. oryzae* during storage. However, many of the popcorn hybrids were highly susceptible to weevil infestation with very low PPE and GPP. For example, PH116 possessed as low as 17.00% PPE and 5.22% GPP. Across locations, 12 hybrids possessed <60% PPE, while 18 hybrids showed <30% GPP. Weevils after infestation lay eggs beneath the pericarp of the grains and the larvae upon hatching grow inside by feeding the endosperm (Danho et al. 2002). Due to damage, popcorn grains fail to show high expansion volume resulting in more number of unpopped kernels that lowers the market value of popcorn (Dowd and Johnson 2010). Various mechanisms for weevil resistance in maize have been reported in many studies. Grain hardness and pericarp thickness were found to be contributory factors for imparting resistance against *S. zeamais* in maize (Arnason et al. 1994; Bergvinson 2001; Siwale et al. 2009). Snout penetration by the weevils into the grains depends on the thickness of the pericarp and hardness of the kernel, and grains with thick pericarp and hard endosperm are tough to penetrate. On the contrary, Zunjare et al. (2014) analysed a set of specialty corn inbreds including popcorn, sweet corn (shrunken and sugary types) and QPM inbreds against *S. oryzae* infestation, and found no association of pericarp thickness and grain hardness with weevil infestation. Further, biochemical properties such as α-amylase- and protease-inhibitors, and phenolics such as (*E*)-ferulic acid have been assigned as the basis of resistance to weevil infestation in maize (Arnason et al. 1994; Garcia-Lara and Bergvinson 2014).

The combined ANOVA revealed significant effects of environments and genotype × environment interactions (G × E) for both PPE and GPP (Table 2). Proportion of sum of square for G × E over total sum of square was 40% and 37%, for PPE and GPP, respectively. This suggests that environmental-factors play important role in governing the popping characteristics of maize grains infested with weevils. Effects of G × E on popping attributes were earlier reported in non-infested grains of popcorn genotypes (Broccoli and Burak 2004; Oz and Kapar 2011).

The present investigation indicated significant genetic variation for popping traits among popcorn hybrids upon infestation of *S. oryzae*. Promising hybrids with high popping quality traits can serve as valuable genetic resources in the breeding programme. Though popcorn genotypes in general display high degree of resistance against weevils compared to other types of maize grains, some of the popcorn hybrids were highly susceptible. Promising popcorn hybrids identified in the study, can be used for deriving new inbreds with desirable popping quality traits in relation to weevil infestation. Parents of hybrids possessing contrasting PPE and GPP, can be used to generate mapping population(s) to localize QTLs for popping quality traits upon infestation by *S. oryzae*.

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