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SCREENING OF COMMON BEAN GENOTYPES FOR THEIR RESISTANCE TO BEAN STEM MAGGOT (OPHIOMYIA SPP.) IN ETHIOPIA

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ABSTRACT

Common bean production in Africa faces various constraints, including biotic and abiotic stress. Among biotic stresses, bean stem maggots (BSM) (*Ophiomyia* spp.) are the most damaging insect pests of common beans in central and sub-Saharan Africa, especially under poor soils and dry conditions. Various control measures are available for bean stem maggots; however, there is insufficient information regarding the resistance of common bean genotypes to this pest. The present study aimed to identify sources of resistance to BSM in two groups of genotypes, namely red mottled and sugar bean, at Negelle Arsi and Shalla in Ethiopia during 2016 and 2017. A total of 111 genotypes with 56 belonging to the red mottled group and 55 to the sugar bean group were assessed for their resistance levels in open fields with a history of BSM infestation following randomized complete block design with three replications. In the 2016 assessment, 23 genotypes exhibited significantly lower numbers of dead seedlings and damage scores in both bean groups and locations. The results for the second year (2017) indicated that four genotypes from the red mottled group (DAB-365, DAB-398, DAB-449, and DAB-331) and four from sugar beans (DAB-500, DAB-512, DAB-483, and DAB-54) were moderately resistant to BSM in both locations. The combined findings from the 2016 and 2017 cropping seasons revealed that DAB-500, DAB-512, DAB-483, and DAB-541 from the red mottled group, and DAB-365, DAB-398, DAB-449, and DAB-331 from the sugar bean group, exhibited resistance to BSM at both locations. Therefore, based on the aforementioned information, these eight genotypes from both groups are recommended as potential sources of resistance to bean stem maggots for further common bean breeding purposes.

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INTRODUCTION

The common bean is a major grain legume consumed worldwide and is the most vital source of proteins for nearly five hundred million people in Africa, Latin America, and the Caribbean, particularly for low-income earning households (Cortes et al., 2013). The common bean holds great significance as the most important crop grown by African farmers in general and Ethiopian farmers in particular (Ampofo et al., 1994). In Ethiopia, it is one of the most important cash crops, and it is utilized as food in various forms. For instance, the green unripe pods are cooked as a vegetable, while the ripe seeds are cooked for "nifro" or boiled mixed with sorghum or maize, and can be consumed as "woti" in powder form (MOARD, 2009).

In Ethiopia, common beans are cultivated under diverse climatic conditions ranging from 1200 to 2400 masl

(Imru, 1985). The Rift Valley area accounts for more than half of the country's common bean production, primarily the white pea bean type grown for export (Ali et al., 2006). However, under optimal management conditions, the productivity of common beans can reach 2.5 to 3.0 tons per hectare in Ethiopia (EPPA, 2004). The national average yield of common beans in Ethiopia is low, ranging from 1.6 t/ha, significantly below the corresponding yield recorded at research sites (2.5-3 t/ha) using improved varieties (CSA, 2015). However, the average yield in 2019 was 1.85 t/ha (CSA, 2018), far below the potential yield of the crop.

Common bean production in Africa faces various constraints, including biotic and abiotic factors. Among the biotic constraints, the damage caused by insect pest infestations under field conditions is significant. The common insect pests attacking common beans in the field include bean stem maggots (BSM) (*Ophiomyia* spp.), African bollworm (*Helicoverpa armigera*), and Aphids (*Aphis fabae*). Of these, BSM is considered a major pest in central and many sub-Saharan African countries, especially under poor soils and dry conditions (Ampofo et al., 1994; Ampofo, 2009).

According to Abate et al. (1990), three species of BSM (*Ophiomyia phaseoli*, *O. spencerella*, and *O. centrosematis*) occur in Ethiopia. Study reports from Ethiopia (Abate et al., 1990), Burundi (Autrique, 1989), Mozambique (Davies, 1990), and Zambia (Sithanantham, 1989) confirm the occurrence and diversity of BSM, categorizing them into three species. In Ethiopia, *O. phaseoli* and *O. spencerella* are the most widely distributed and abundant of the three species. However, *O. centrosematis* occurs rarely and represents less than 2% of the total BSM population (Wondimu et al., 2017).

The incidence of BSM species is influenced by one or a combination of environmental factors and cultural practices, including altitude, sowing date, growth stage, and the type of host plant. *O. phaseoli* and *O. centrosematis* are more prevalent in warmer areas, mostly in the south and southwestern part of the country, at elevations of < 1800 meters above sea level, whereas *O. spencerella* is dominant at higher altitudes (cooler and wetter conditions) (Wondimu et al., 2017).

The bean stem maggot attacks the bean plant as soon as the first pair of leaves begins to unfold (Odendo et al., 2005). It is most severe in late or off-season planted crops (Nderitu et al., 1990; Ochilo and Nyamasyo, 2011), hotter drier seasons, and in plants under stress such as poor soil fertility (Ampofo et al., 1994; Wang and Gai, 2001; Ojwang et al., 2010). Severe bean stem maggot attacks, especially during the early stages of plant growth, cause high yield losses. In Africa, yield losses ranging from 80 to 100% have been reported (Ochilo and Nyamasyo, 2011; Munyasa, 2013).

Various control methods have been recommended for the management of BSM, including the use of resistant varieties such as 'Beshbesh' and 'Melkae' (Tsedeke, 1990), intercropping, foliar insecticide application (Byabagambi et al., 1999), the use of deep straw mulching (Letourneau, 1994), and seed dressing (Byabagambi and Kyamanywa, 1997). Currently, the bean variety 'Melkae', which was previously reported as resistant, is becoming less resistant to BSM (Mulatwa, 2017). Moreover, new materials, both market types, and BSM-resistant varieties are being introduced from CIAT regularly. Therefore, the present study was conducted to identify genotypes resistant to bean stem maggot (*Ophomya* spp).

MATERIALS AND METHODS

Description of the study area

A field experiment was conducted in Negelle Arsi and Shalla districts during the main common bean growing season in 2016 and 2017, under rain-fed conditions. Negelle Arsi is situated in the West Arsi zone of the Oromia Regional State, Ethiopia, 277 km south of Addis Ababa. The district spans latitudes between 7.15°N and 7.75°N, and longitudes between 38.35°E and 38.95°E. The altitude of the district ranges from 1500 to 3000 meters above sea level. The average annual temperature fluctuates between 10°C and 25°C, while annual rainfall varies between 500 and 1000 mm.

Shalla district is located in the West Arsi zone, approximately 270 km southwest of Addis Ababa. The area is a lowland with an altitude of 1550 meters above sea level, situated at a latitude of 38° 27'10.9''E and a longitude of 7°17'08.6''N. The site experiences a mean maximum temperature of 29.2°C and a mean minimum temperature of 14.4°C. The soil texture is sandy loam, and the site receives a mean annual rainfall of 763 mm, with significant variation in distribution. Approximately 70% of the rainfall occurs between the months of May and September.

Treatments

Two groups of bean genotypes, namely 'Red Mottled' and 'Sugar Bean', initially introduced from CIAT, were collected from the national bean breeding program based at Melkassa. The Red Mottled group comprised 56 genotypes, and the Sugar Bean group comprised 55 genotypes, totaling 111 genotypes. All genotypes were multiplied during the off-season to obtain a sufficient amount of seeds. The experiment was arranged in a randomized complete block design with three replications.

Data collection and analysis

The percentage of seedling mortality was assessed by counting the number of dead seedlings per plot, following the method described by Ampofo et al. (1987).

$$PD = \frac{NDP}{TSC/P} \times 100$$

Where PD = Percent damaged plants, NDP = No. of damaged plants per plot, TSC/P = Total stand count per plot.

Seedling mortality data were collected three times, starting two weeks after plant emergence. Severity scores were taken on a 0-5 scale where: 0 = no infestation, 1 = less infested, 2 = infested, 3 = highly infested, 4 = severely infested, 5 = dead plants (Ampofo et al., 1987).

Ten plants per plot were randomly sampled and cut at ground level using a knife. Subsequently, the number of BSM larvae and/or pupae was recorded by examining the stem. Pupa color was utilized for species identification; brown pupa indicated *O. phaseoli*, while black pupa indicated *O. spencerella*. The data were analyzed using SAS Software version 9.0. Percent mortality data underwent square root transformation before analysis. Significant means ($p < 0.05$) were distinguished using Tukey's standardized range test (HSD).

RESULTS

Damage severity and mortality of bean stem maggot infestation at Arsi Negele

Twelve genotypes from the red mottled group (DAB-500, DAB-515, DAB-506, DAB-512, DAB-483, DAB-520, DAB-539, DAB-525, DAB-528, DAB-541, and DAB-545) and eleven genotypes from the sugar bean group (DAB-365, DAB-393, DAB-447, DAB-355, DAB-449, DAB-331, DAB-423, DAB-380, DAB-388, DAB-393, DAB-398, and DAB-402) exhibited lower seedling mortality and damage severity at Negelle Arsi in 2016 (Table 1).

Table 1. Mean (±se) severity score and mean (± se) percent mortality of red mottled and sugar bean genotypes of common bean against BSM at Arsi Negele, 2016 (pooled data).

Red mottled	Severity score	Mortality%	Sugar bean	Severity score	Mortality %
DAB-500	1.00 ± 0.01 c	1.858 ± 0.01 c	DAB-365	1.67 ± 0.01 c	1.09 ± 0.06 c
DAB-515	1.00 ± 0.01 c	1.943 ±0.01 c	DAB-366	3.33 ± 0.01 ab	5.66 ± 0.02 a
DAB-506	1.33 ± 0.01 c	2.778 ± 0.03 ab	DAB-447	1.33 ± 0.01 c	2.78 ± 0.04 ab
DAB-512	1.67 ± 0.01 b	2.877 ± 0.03 ab	DAB-393	1.00 ± 0.01 c	1.93 ± 0.03 c
DAB-483	1.67 ± 0.01 b	2.729 ± 0.03 ab	DAB-398	1.01 ± 0.01 c	1.66 ± 0.02 c
DAB-520	1.56± 0.01 b	2.778 ± 0.03 ab	DAB-355	1.67 ± 0.01 c	3.91 ± 0.04 ab
DAB-539	1.67 ± 0.01 b	2.632 ± 0.03 ab	DAB-402	1.33 ± 0.01 c	1.90 ± 0.02 c
DAB-525	1.67 ± 0.01 b	2.729 ± 0.03 ab	DAB-449	1.00 ± 0.01 c	2.73 ± 0.03 ab
DAB-528	1.67 ± 0.01 b	2.632 ± 0.03 ab	DAB-331	1.33 ± 0.01 c	3.95 ± 0.04 ab
DAB-541	1.67 ± 0.01 b	2.123 ± 0.02 ab	DAB-388	1.00 ± 0.01 c	1.90 ± 0.02 c
DAB-545	1.00 ± 0.01 c	1.887 ± 0.02 c	DAB-423	1.67 ± 0.01 c	2.16 ± 0.02 ab
DAB-537	2.7 ± 0.03 ab	6.54 ± 0.07 a	DAB-380	1.67 ± 0.01 c	2.17 ± 0.02 ab
DAB-492	3.89 ± 0.04 ab	5.32 ± 0.06 a	DAB-420	4.30 ± 0.05 ab	3.80± 0.04 ab
DAB-499	4.6 ± 0.05 a	4.43 ± 0.05 ab	DAB-442	5.6 ± 0.06 a	4.20± 0.05 a
DAB-525	3.5 ± 0.04 ab	5.98 ± 0.06 a	DAB-442	6.21 ± 0.06 a	4.50± 0.06 a
DAB-417	4.1 ± 0.05 a	3.60 ± 0.05 ab	DAB-445	4.00 ± 0.05 ab	3.70± 0.05 ab

Means followed by the same letter within a column are not significantly different from each other, 5% HSD.

Conversely, the genotypes DAB-537, DAB-492, DAB-499, and DAB-417 from the red mottled group, as well as the genotypes DAB-366, DAB-420, DAB-442, DAB-442, DAB-442, and DAB-445 from the sugar bean group, demonstrated significantly higher seedling mortality and damage scores (P < 0.05) (Table 2). Based on the mean severity score and mortality, DAB-499 and DAB-537 from the red mottled group, and DAB-442 and DAB-366 from the sugar bean group, were the most severely affected.

Bean stem maggot severity and mortality at Shalla in 2016

DAB-500, DAB-515, DAB-483, DAB-539, DAB-528 and DAB-545 (red mottled group) and DAB-365, DAB-366, DAB-447, DAB-331 and DAB-449 (sugar bean group) resulted in lower seedling mortalty and damage score at Shalla in 2016 (Table 2).

Red mottled genotypes DAB-506, DAB-512, DAB-520, DAB-525and DAB-541 resulted in significantly (p<0.05) higher seedling mortality and severity score. From sugar bean group, DAB-366 and DAB-388 resulted in higher seedling mortality and damage score (Table 2). Based on the mean severity score and mortality rate, DAB-506 and DAB-541 were the most infested genotypes among red mottled. By the same token, DAB-355 and DAB-366 from the sugar bean group were the highest infested (Table 2).

Table 2. Mean (±se) severity score and mean (±se) percent mortality of Red mottled and Sugar bean genotypes of common bean against BSM at Shalla, 2016 (pooled data).

Red mottled	Severity score	Mortality %	Sugar bean	Severity score	Mortality %
DAB-500	1.27 ± 01 ab	3.45 ± 02 a	DAB-365	1.00 ± 01 b	1.56 ± 01 b
DAB-515	1.00 ± 01 b	2.00 ± 02 ab	DAB-366	3.37 ± 03 a	2.75 ± 01 ab
DAB-506	2.67 ± 01 a	4.80 ± 02 a	DAB-447	1.67 ± 01 b	1.23 ± 02 b
DAB-512	2.00 ± 01 ab	2.67 ± 02 ab	DAB-393	1.00 ± 02 b	1.34 ± 02 b
DAB-520	2.00 ± 01 ab	2.80 ± 02 ab	DAB-355	1.67 ± 02 b	3.91 ± 01 a
DAB-539	1.00 ± 01 b	2.63 ± 02 ab	DAB-402	1.35 ± 02 b	1.90 ± 01 b
DAB-525	2.00 ±01 ab	4.56 ± 02 a	DAB-449	1.23 ± 02 b	2.738 ± 01 ab
DAB-528	1.00 ± 01 b	2.63 ± 02 ab	DAB-331	1.33 ± 03 b	2.95 ± 01 ab
DAB-541	2.00 ± 01 ab	5.10 ± 02 a	DAB-388	2.32 ± 01 ab	1.90 ± 02 b
DAB-545	0 ± 01 c	0.00 ± 02 c	DAB-423	1.69 ± 01 b	2.16 ± 02 ab

Means followed by the same letter within a column are not significantly different from each other, 5% HSD.

Bean stem maggot pupae population at Negelle Arsi and Shalla in 2016 and 2017

The pupae population was lower on genotypes DAB-500, DAB-515, DAB-506, DAB-512, DAB-483, DAB-492, and DAB-545 in the red mottled group. In contrast, in the sugar bean group, lower pupae population was recorded on DAB-365, DAB-393, DAB-449, DAB-355, and DAB-331 (Table 3 and 4).

Bean stem maggot severity and mortality at Negelle Arsi in 2017

Four genotypes belonging to red mottled group including DAB-500, DAB-512, DAB-483 and DAB-541 showed the lowest percent mortality and lowest severity score (Table 5). Similarly, from sugar bean groups, DAB-365, DAB-398, DAB-449, DAB-331, showed similar results at Negelle Arsi in 2017 (Table 5).

Bean Stem maggot severity and mortality at Shalla in 2017

Among the red mottled group, DAB-500, DAB-512, DAB-483, and DAB-541 exhibited lower mortality and severity scores.

Similarly, sugar bean genotypes, specifically DAB-365, DAB-398, DAB-449, and DAB-331, also demonstrated lower mortality and severity scores at Shalla in 2017 (Table 6).

DISCUSSION

Due to the high genotype variation, the evaluation and selection of germplasm for bean stem maggot resistance should be conducted in a production environment with a history of pest damage (Wilson et al., 2021). Common bean resistance to bean stem maggot is associated with agro-morphological traits such as stem diameter, length of internode on the main stem, leaf hairiness, and phenolic compounds (Ambachew et al., 2015). These and other quantitative traits are controlled by many sets of minor genes in common bean (Wilson et al., 2021).

The results of this study revealed that 12 genotypes from red mottled and 11 genotypes from sugar bean showed a good level of resistance to BSM, with a smaller pupae population, especially on DAB-500, DAB-515, DAB-506, DAB-512, DAB-483, DAB-492, DAB-545, and DAB-365. For sugar bean, DAB-393, DAB-449, DAB-355, DAB-331 genotypes showed a good level of resistance at Negelle Arsi in 2016. At Shall, six and five red mottled and sugar bean genotypes, respectively, in the same year showed a good level of resistance to BSM.

Table 3. Mean number of pupae of *O. phaseoli* in Red mottled genotypes at Arsi-Negelle and shalla.

Red mottled	Year 2016/17	
	Mean Number of Pupa	
	Negelle Arsi	Shalla
DAB-500	1.33 d	1.215 c
DAB-515	2.67 d	1.585 bc
DAB-506	1.5 d	1.75 b
DAB-512	1.8 cd	1.5 bc
DAB-483	1.00 d	1.5 bc
DAB-520	3.0 abcd	3.00 a
DAB-539	4.67 abc	2.67 a
DAB-492	1.8 cd	1.10 c
DAB-545	1.6 d	1.20 c
DAB-537	3.00 abcd	3.10 a
DAB-492	3.33 abcd	1.30 c
DAB-499	5.33 ab	2.20 ab
DAB-525	4.500 abc	1.3 c
DAB-553	3.00 abcd	3.00 a
DAB-537	3.00 abcd	2.10 b
LSD	4.86	4.50

Means followed by the same letter within a column are not significantly different from each other, 5% HSD.

Table 4. Mean number of pupae of *O. phaseoli* in Sugar bean genotypes at Arsi-Negelle and shalla.

Sugar bean	Year 2016/17	
	Mean Number of Pupa	
	Negelle Arsi	Shalla
DAB-365	1.185 c	1.25 b
DAB- 366	4.50 b	1.50 b
DAB-393	2.00 c	2.10 b
DAB- 355	1.650 c	2.00 b
DAB-402	1.10 c	1.30 b
DAB-449	1.00 c	3.00 a
DAB-388	2.00 c	1.90 b
DAB-423	2.00 c	2.30 b
DAB-380	5.50 b	1.70 b
DAB-417	7.50 a	2.20 b
LSD	4.60	4.50

Means followed by the same letter within a column are not significantly different from each other, 5% HSD.

The significant impact of genotype, location, and year interaction effects on bean stem maggot resistance parameters suggests considerable genetic diversity among the genotypes for gene interaction, which needs further verification through molecular detection. The study noted that trait expression was influenced by both genotype and environment.

In further screening in 2017 at both locations, four genotypes from each common bean group were found to be highly resistant to BSM with the smallest number of pupae. The existence of variability in susceptibility or resistance to BSM observed in this study is in line with that of Kipto et al. (2016), who reported common bean genotypes named KK 8, Tasha, KK 15, Chelalang, GLP 585, and GLP 1004 as resistant to BSM, while genotypes Wairimu dwarf, Ciankui, Miezimbili, GLP 2, GLP 24, and GLP 1127 as susceptible to BSM in Kenya.

Table 5. Mean (±se) severity score and mean (±se) percent mortality of Red mottled and Sugar bean genotypes of common against BSM at Negelle Arsi, 2017 (Pooled data)

Red mottled	Severity score	Mortality %	Sugar bean	Severity score	Mortality %
DAB-500	1.12±0.1b	2.56±0.2ab	DAB-365	1.2±02b	2.1±02ab
DAB- 515	1.3±0.1b	4.75±0.2ab	DAB- 366	1.12±0.3b	3.21±0.1ab
DAB- 506	2.67±0.1ab	4.2±0.1a	DAB- 447	1.47±0.1b	1.3±0.1b
DAB-512	1.2±0.2b	2.34±0.2ab	DAB-393	2.2±0.2ab	1.0±0.2b
DAB-483	1.2±0.2b	2.667±0.3ab	DAB-398	2.4±0.3ab	5.1±0.2a
DAB-520	3.2±0.2a	3.91±0.2ab	DAB- 355	3.4±0.2a	3.0 ±0.3ab
DAB-539	2.4±0.2ab	2.90±0.4ab	DAB-402	3.2±0.3a	1.0±0.3b
DAB- 525	2.5±0.2ab	4.738±0.2a	DAB- 449	3.1±0.3a	2.0±0.2ab
DAB- 528	1.2±0.1b	3.95±0.4a	DAB- 331	3.12±0.2a	2.0±0.4ab
DAB-541	1.12±0.1b	2.90±0.5ab	DAB-388	2.12±0.3ab	2±0.3ab
DAB- 545	3.2±0.1a	2.16±0.6ab	DAB- 423	2.1±0.3ab	2.0±0.2ab
DAB- 540	3.4±0.1a	2.67±0.4ab	DAB-380	3.2±0.1a	3.0±0.2ab

Means followed by the same letter within a column are not significantly different from each other, 5% HSD

Table 6. Mean (±se) severity score and mean (±se) percent mortality of Red mottled and Sugar bean genotypes of common bean against BSM at Shalla, 2017 (Pooled data).

Red mottled	Severity score	Mortality %	Sugar bean	Severity score	Mortality %
DAB-500	1.00 ± 0.1 b	3.56 ± 0.3 ab	DAB-365	1.1 ± 0.1 b	2.56 ± 0.2 ab
DAB-515	1.37 ± 0.1 b	4.75 ± 0.3 a	DAB-366	1.37 ± 0.1 b	2.75 ± 0.2 ab
DAB-506	3.67 ± 0.3 a	4.2± 0.3 a	DAB-447	1.67 ± 0.1 b	1.23 ± 0.1 b
DAB-512	2.1 ± 0.2 ab	5.3 4± 0.4 a	DAB-393	2.0 ±0.2 ab	1.34 ± 0.1 b
DAB-483	1.2 ± 0.1 b	5.66 7± 0.3 a	DAB-398	1.1 ± 0.1 b	1.667 ± 0.1 b
DAB-520	2.2 ± 0.2 ab	3.91 ± 0.2 ab	DAB-355	1.67 ± 0.1 b	3.91 ± 0.3 a
DAB-539	3.4 ± 0.3 a	2.90 ± 0.2 ab	DAB-402	1.35 ± 0.1 b	1.90 ± 0.1 b
DAB-525	1.5 ± 0.1 b	2.738 ± 0.1 ab	DAB-449	1.23 ± 0.1 b	2.738 ± 0.2 ab
DAB-528	3.2 ± 0.3 a	3.95 ± 0.2 ab	DAB-331	1.33 ± 0.1 b	3.95 ± 0.2 a
DAB-541	2.12 ± 0.2ab	4.90 ± 0.3 a	DAB-388	2.32 ± 0.2ab	1.90 ± 0.1 b
DAB-545	2.2 ± 0.2 ab	2.16 ± 0.1 ab	DAB-423	1.69 ± 0.1 b	2.16 ±0.2 ab

Means followed by the same letter within a column are not significantly different from each other, 5% HSD.

Previous works in Ethiopia documented that the bean genotypes Melke and Beshbesh were registered as BSM-resistant varieties (Tsedeke, 1990). However, after a decade and a half, these two varieties were tested for their reaction to BSM in BSM hot spot areas. The results obtained proved that Melkae became susceptible to BSM, while Beshebshe remained resistant to BSM (Mulatwa et al., 2017).

CONCLUSION

The study identified a considerable genetic difference in bean stem maggot resistance among the evaluated genotypes. The current experiment confirmed the presence of resistant genes to BSM in both red mottled and sugar bean groups of common beans, which can serve as a resistance source for a breeding program targeting high-yielding and BSM-resistant common bean varieties. Among the red mottled common bean genotypes, DAB-500, DAB-512, DAB-483, and DAB-541, as well as sugar bean genotypes DAB-365, DAB-398, DAB-449, and DAB-331, were found to be resistant to BSM in two locations during the two consecutive cropping seasons of 2016 and 2017.

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AUTHOR'S CONTRIBUTION
MW designed the study, conducted the experiments, collected and analyzed the data, wrote the manuscript and proofread the paper.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

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