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Combination of Vermiwash and Biopesticides against Aphid (*Lipaphis erysimi*) Infestation and their Effect on Growth and Yield of Mustard (*Brassica campestris*)

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ABSTRACT

Vermiwash (VW), singly and in combination with different biopesticides (BPs), was used in an agricultural field to control aphid (*Lipaphis erysimi*) infestation and to increase the growth and yield of mustard (*Brassica campestris*). A significant reduction in the aphid population was observed on mustard plants after spraying VW obtained from different combinations of animal dung and agro-wastes with 95% neem (*Azadirachta indica*) oil and 86% custard apple (*Annona squamosa*) leaves. The combination of garlic (*Allium sativum*) extract with different VWs could control 97% of the aphid population. VW obtained from animal dung + gram bran with neem oil was also very effective against aphids. A VW spray with BP increased the productivity of the mustard crop up to 3.5 times more than the control. These results clearly demonstrate that the use of VW with plant products is more beneficial for organic farming. It also compensates for deficiencies in essential nutrients, certain plant growth hormones, enzymes and vitamins. VW, singly and in combination with plant products, provides effective control against aphids, which are injurious to mustard plants.

Keywords: aphid, biopesticide, *Brassica campestris*, *Eisenia foetida*, productivity, vermicomposting, vermiwash
Abbreviations: BP, biopesticide; **VW**, vermiwash

INTRODUCTION

Mustard (*Brassica campestris*; Brassicaceae) is the main oil crop of India. The seed oil content varies from 30 to 48% depending on the variety and soil condition. The oil contains 7% moisture, 36% fats, and 25% nitrogenous substances. Erucic acid is one of the characteristics of the fatty acid of mustard oil. Oleic, linoleic, palmitic, stearic and linoceric acids are another important fatty acids present in mustard oil. Mustard oil is chiefly used for edible purposes. Inferior grades of oil are used as illuminant, for oiling wooden articles and in the manufacture of soap and rubber substitutes. The oil is also used as a preservative for pickles and for flavoring curries and vegetables (Singh *et al.* 2005). The application of chemical fertilizers and synthetic pesticide to increase the productivity of crops and to manage pests is one of the serious threats to the environment and human health (Levi 2000; Mall *et al.* 2005). The regular cultivation of land without the incorporation of organic matter deteriorates soil quality (Meena 2007) thus management of soil quality through the use of organic fertilizer is important. Consequently, more biological wastes are used to produce biofertilizers (Gupta 2005). Vermicomposting is a suitable way to manage waste with the help of earthworms such as *Eisenia foetida*. Vermiwash (VW) is a useful product of vermiculture which contains micronutrients vitamins, hormones, and elements endowing it with disease resistance (Pathak and Ram 2004). It is a liquid organic biofertilizer with pesticidal properties (Kale 1998; Umamaheswari *et al.* 2003; Shivsubramanian and Ganeshkumar 2004). Gamaley *et al.* (2001) suggested that VW is a foliar manure that can be used to optimize the productivity of various agricultural crops.

Aphids belong to the Aphididae family, order Hemiptera. *Lipaphis erysimi* is a popular pest of mustard and other species of the Brassicaceae. Both nymph and adult aphids attack all aerial parts of the mustard plant (Singh 2005) and directly damage the plant by sucking its nutrients resulting in general devitalisation of the plant. They also indirectly affect the health of the plant by their copious secretion of honey-dew that occludes the stomatal opening of the leaves; hence the physiological process like photosynthesis and respiration are disturbed (Singh 2005). Severe destruction of the plant occurs during flowering and fruiting stages: the adult aphid and its nymph damages flower and up to 90% of the total production (Singh 2005; Shukla and Upadhyay 2007). The use of organic material as a foliar spray for the management of mustard aphid to increase crop production is an appropriate organic farming technique. Different plant (neem, garlic and custard apple) parts have pesticidal properties (Gupta and Sharma 1993; Akhtar 2004; Akhtar and Mahmood 2004). Pavela *et al.* (2004) suggested that azadirachtin significantly increased the mortality but decreased the development and fecundity of cabbage aphid (*Brevicoryne brassicae*). Koul (1999) reported that neem seed extract inhibit the growth of rose aphid (*Microsiphum rosae*) and chrysanthemum aphid (*Macrosiphoniella sanbornii*). El-Hawary and El-Salam (2008) reported that nimbecidine was more effective than Green Miracle against *Aphis craccivora*. Garlic produces a variety of volatile sulphur compounds which are used as insect repellents and insecticides (Kaufmain *et al.* 1999; Park *et al.* 2006; Prowse *et al.* 2006). Different garlic products that are recognized as insecticides are also used against mites, nematodes and mosquito larvae affecting a variety of crops (Gupta and Sharma 1993; Gambola-Leon *et al.* 2006). Different combinations of neem and custard apple seed oil are effective against the aphid *Nephotettix virescens*, which transmits *Rice tungro virus* (Mariappan and Saxena 1983).

The objective of this study was to investigate the effect of VW of different animal (cow, buffalo, sheep, goat and horse) dung and agro-kitchen waste, singly and in com-

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bination with different plant products against the mustard aphid *Lipaphis erysimi* and their effect on growth, flowering as well as productivity of the mustard crop.

MATERIALS AND METHODS

Collection of wastes

Animal (cow, buffalo, sheep, horse and goat) dung was collected from different farm houses of Gorakhpur City. Different agro wastes (gram bran, straw, wheat bran, barley bran and rice bran) and vegetable wastes were collected from rural and urban parts of Gorakhpur district. Partially decomposed mixtures of animal dung and agro-kitchen wastes were used to enhance vermicomposting efficiency. For this purpose, a mixture of organic wastes was sprayed in a layer of 30-60 cm and exposed to sunlight for 5 to 10 days to remove various harmful organism and noxious gases (Bhatnagar and Palta 1998).

Collection of earthworms

Earthworms (*Eisenia foetida*), an epigeic species, were cultured in the laboratory at 20-30°C, aeration, and 40-60% relative moisture for proper growth and survival of earthworms (Gupta 2005). The temperature and moisture were maintained by spraying of water required and aeration by weekly turn over up to three week.

Preparation of vermicomposts

35 vermibeds were formed by different combinations of animal dung and agro-kitchen wastes in a 1: 1 ratio (w/w) on a surface cement. This ratio was appropriate for the proper development of earthworms. The size of each vermibed was 3 m × 1 m × 9 cm. After the vermibed was prepared, it was moistened and inoculated with 2 kg of young cultured *E. foetida* in each bed. The beds were covered with discarded jute and the bed was moistened daily for up to 40 to 50 days for maintaining the moisture content. After one week and for a total of 3 weeks, the bed's mixture was turned manually. After 50 to 60 days, a granular tea-like material i.e. VC appeared on each vermibed.

Extraction of vermiwash

VW was extracted from a VW-collecting device by the method of Ismail (1997). The apparatus was made from a plastic drum having a 2-L capacity and a tap at the bottom. The drum was filled with broken bricks to about 3 cm thick then by a 2-3 cm sand layer. Finally, it was filled with VC and a heavy population of earth-

Table 1 Effect of vermiwash (10 mg/m^2) of different animal dung and agro / kitchen wastes on aphid population and growth as well as flowering productivity of mustard (*Brassica campestris*).

Vermiwash	No. of aphids				Growth of mustard (cm)	Flowering period (days)	Productivity (kg/m^2) after harvesting
	Before spraying	After first spraying	After second spraying	After third spraying	After 50 days		
Control	46.2 ± 4.4	67.4 ± 2.2	72.2 ± 5.8	83.5 ± 3.8	31.60 ± 2.56	52.4 ± 3.2	0.12 ± 0.02
Cow							
Dung	# 45.6 ± 2.2	30.5 ± 3.3	22.6 ± 2.6	16.3 ± 2.6	# 49.27 ± 1.64	37.6 ± 2.2*	# 0.19 ± 0.04
Dung +Rice Bran	$ 47.2 ± 2.1	31.3 ± 2.2	24.2 ± 1.9	15.6 ± 3.5	45.96 ± 2.46	36.5 ± 2.8*	0.20 ± 0.05
Dung +Wheat Bran	46.4 ± 3.2	32.5 ± 5.3	23.6 ± 3.9	15.9 ± 2.4	46.20 ± 2.64	36.4 ± 3.4*	0.20 ± 0.01
Dung +Straw	47.2 ± 5.3	28.4 ± 4.2	24.5 ± 2.5	14.5 ± 1.8	47.42 ± 1.22	37.9 ± 2.5*	0.21 ± 0.06
Dung +Vegetables	48.4 ± 3.2	32.6 ± 2.2	22.6 ± 1.6	15.9 ± 2.2	42.32 ± 2.10	36.8 ± 2.8*	0.20 ± 0.08
Dung +Barley Bran	45.3 ± 4.3	32.9 ± 2.1	23.2 ± 3.2	13.9 ± 3.4	43.25 ± 1.92	39.2 ± 2.4*	0.21 ± 0.05
Dung +Gram Bran	48.3 ± 3.2	27.8 ± 3.3	23.3 ± 4.4	12.8 ± 2.2	52.12 ± 1.36	35.7 ± 2.7*	0.22 ± 0.02
Buffalo							
Dung	# 45.3 ± 2.2	32.3 ± 2.1	21.2 ± 1.4	17.3 ± 1.4	# 42.17 ± 0.16	36.2 ± 2.4*	# 0.20 ± 0.02
Dung +Rice Bran	$ 46.4 ± 3.3	32.3 ± 3.3	24.5 ± 2.9	16.2 ± 2.7	46.23 ± 2.88	36.4 ± 1.6*	0.21 ± 0.01
Dung +Wheat Bran	47.5 ± 4.2	32.5 ± 2.2	22.2 ± 3.9	16.2 ± 2.4	42.07 ± 2.49	35.2 ± 2.6*	0.22 ± 0.06
Dung +Straw	51.4 ± 2.2	28.4 ± 1.3	23.1 ± 2.4	15.3 ± 3.8	46.20 ± 2.12	34.8 ± 1.6*	0.22 ± 0.08
Dung +Vegetables	47.6 ± 5.2	29.6 ± 3.2	25.9 ± 4.4	15.7 ± 2.7	47.52 ± 3.92	34.8 ± 2.4*	0.23 ± 0.04
Dung +Barley Bran	47.4 ± 4.2	31.4 ± 4.2	25.9 ± 3.6	12.9 ± 3.6	45.50 ± 2.33	33.4 ± 2.4*	0.22 ± 0.00
Dung +Gram Bran	45.8 ± 2.3	26.8 ± 2.1	25.8 ± 1.8	12.8 ± 2.6	55.35 ± 2.23	32.4 ± 2.2*	0.24 ± 0.06
Sheep							
Dung	# 47.5 ± 2.0	31.3 ± 2.2	25.6 ± 1.2	18.5 ± 3.9	# 35.64 ± 2.25	38.9 ± 2.4*	# 0.15 ± 0.02
Dung +Rice Bran	$ 48.5 ± 3.3	32.5 ± 3.2	28.9 ± 2.9	17.3 ± 3.3	38.56 ± 0.43	36.4 ± 2.5*	0.18 ± 0.04
Dung +Wheat Bran	47.6 ± 4.1	32.4 ± 3.3	29.2 ± 4.9	17.3 ± 4.7	41.15 ± 2.55	37.8 ± 2.3*	0.16 ± 0.00
Dung +Straw	48.3 ± 5.1	29.7 ± 2.1	28.2 ± 5.6	20.8 ± 2.8	36.26 ± 2.43	37.5 ± 4.5*	0.17 ± 0.01
Dung +Vegetables	45.4 ± 2.3	21.3 ± 2.2	27.5 ± 3.8	21.0 ± 2.8	45.94 ± 1.60	38.8 ± 3.4*	0.17 ± 0.06
Dung +Barley Bran	46.4 ± 1.2	32.7 ± 3.2	22.8 ± 2.0	20.2 ± 3.3	39.53 ± 2.70	38.3 ± 3.6*	0.18 ± 0.06
Dung +Gram Bran	45.5 ± 2.1	31.6 ± 4.3	20.6 ± 3.0	20.8 ± 2.6	47.32 ± 2.33	36.3 ± 2.6*	0.20 ± 0.03
Goat							
Dung	# 45.3 ± 3.2	33.3 ± 2.3	20.6 ± 2.3	21.0 ± 3.4	# 29.30 ± 2.63	38.5 ± 0.7*	# 0.15 ± 0.05
Dung +Rice Bran	$ 47.8 ± 2.1	30.8 ± 3.1	21.4 ± 4.4	21.3 ± 3.2	31.19 ± 1.58	37.2 ± 2.6*	0.17 ± 0.01
Dung +Wheat Bran	47.5 ± 2.0	34.2 ± 3.4	20.3 ± 1.9	20.8 ± 2.5	30.44 ± 1.42	36.5 ± 0.7*	0.19 ± 0.04
Dung +Straw	46.2 ± 5.0	30.5 ± 2.1	29.2 ± 2.8	19.6 ± 3.6	32.00 ± 2.45	36.4 ± 2.8*	0.18 ± 0.02
Dung +Vegetables	46.3 ± 4.2	32.6 ± 2.0	21.7 ± 3.7	20.7 ± 3.5	38.85 ± 2.43	39.6 ± 2.7*	0.17 ± 0.04
Dung +Barley Bran	47.4 ± 3.1	34.8 ± 4.1	21.8 ± 2.2	20.9 ± 2.7	35.72 ± 1.53	37.5 ± 2.4*	0.16 ± 0.03
Dung +Gram Bran	48.4 ± 4.2	33.3 ± 3.1	20.3 ± 2.8	20.1 ± 2.2	45.23 ± 0.32	37.8 ± 3.2*	0.21 ± 0.00
Horse							
Dung	# 49.5 ± 4.1	30.4 ± 2.2	23.2 ± 3.3	19.9 ± 2.5	# 40.56 ± 0.52	36.2 ± 1.7*	# 0.20 ± 0.01
Dung +Rice Bran	$ 47.4 ± 5.2	29.6 ± 1.2	22.2 ± 2.7	21.3 ± 3.6	45.82 ± 1.60	34.5 ± 2.3*	0.21 ± 0.00
Dung +Wheat Bran	45.3 ± 6.2	32.7 ± 3.1	22.8 ± 2.6	20.3 ± 4.4	46.24 ± 2.53	34.6 ± 0.5*	0.21 ± 0.04
Dung +Straw	47.6 ± 3.3	29.6 ± 2.1	23.2 ± 2.2	21.6 ± 2.4	42.52 ± 0.53	35.8 ± 0.6*	0.23 ± 0.09
Dung +Vegetables	46.4 ± 2.1	32.5 ± 2.2	25.5 ± 3.4	21.3 ± 2.4	45.34 ± 2.59	36.4 ± 2.8*	0.23 ± 0.04
Dung +Barley Bran	45.3 ± 2.3	33.4 ± 2.4	26.2 ± 4.6	20.8 ± 3.5	43.52 ± 2.53	34.7 ± 2.7*	0.24 ± 0.01
Dung +Gram Bran	42.2 ± 4.0	28.2 ± 2.3	25.8 ± 2.6	20.8 ± 3.2	51.33 ± 1.43	33.5 ± 3.1*	0.25 ± 0.02

Each value is the mean ± SE of 6 replicates. 2-way ANOVA: Significant ($P < 0.05$) $ within column, # within row.
* Significant ($P < 0.05$, *t*-test) between treated and control group.

Table 2 Effect of vermiwash of different animal dung and agro / kitchen wastes (10 mg/m^2) with neem oil (10:1) on aphid population as well as growth and productivity of mustard (*Brassica campestris*).

Vermiwash	No. of aphids				Growth of mustard (cm)	Flowering period (days)	Productivity (kg/m^2) after harvesting
	Before spraying	After first spraying	After second spraying	After third spraying	After 50 days		
Control	46.2 ± 4.4	67.4 ± 2.2	72.2 ± 5.8	83.5 ± 3.8	31.60 ± 2.56	52.4 ± 3.2	0.12 ± 0.02
Cow							
Dung	# 45.4 ± 2.2	22.3 ± 2.4	13.7 ± 2.3	3.6 ± 0.6	# 39.12 ± 2.24	34.8 ± 2.2*	# 0.36 ± 0.04
Dung +Rice Bran	$ 46.3 ± 3.3	24.6 ± 3.8	14.2 ± 1.4	3.5 ± 0.3	46.14 ± 2.72	33.4 ± 1.8*	0.37 ± 0.05
Dung +Wheat Bran	48.3 ± 3.2	23.7 ± 2.5	14.9 ± 1.5	1.6 ± 0.4	42.21 ± 3.54	33.6 ± 2.2*	0.37 ± 0.01
Dung +Straw	47.6 ± 2.3	25.6 ± 1.8	16.5 ± 2.4	3.7 ± 1.1	46.43 ± 4.24	32.0 ± 2.5*	0.38 ± 0.06
Dung +Vegetables	45.5 ± 4.1	24.1 ± 2.9	13.7 ± 2.6	4.4 ± 1.2	44.42 ± 5.26	32.8 ± 2.7*	0.39 ± 0.05
Dung +Barley Bran	48.4 ± 3.3	24.4 ± 1.5	16.2 ± 1.8	4.5 ± 0.4	45.45 ± 2.33	34.2 ± 1.6*	0.34 ± 0.05
Dung +Gram Bran	49.8 ± 2.2	24.9 ± 3.6	14.3 ± 3.4	0	45.46 ± 4.30	32.5 ± 1.4*	0.40 ± 0.02
Buffalo							
Dung	# 46.7 ± 2.0	22.2 ± 4.3	12.5 ± 2.4	2.6 ± 0.3	# 48.07 ± 2.16	34.8 ± 1.2*	# 0.38 ± 0.02
Dung +Rice Bran	$ 46.2 ± 2.1	23.2 ± 0.9	15.6 ± 3.4	2.5 ± 0.4	46.40 ± 2.44	32.4 ± 1.2*	0.42 ± 0.05
Dung +Wheat Bran	47.6 ± 3.2	23.2 ± 2.4	14.2 ± 2.8	3.8 ± 0.3	44.12 ± 4.54	32.2 ± 0.9*	0.38 ± 0.02
Dung +Straw	47.4 ± 2.1	24.2 ± 3.8	14.2 ± 1.9	3.3 ± 0.2	43.81 ± 3.95	31.8 ± 0.8*	0.42 ± 0.08
Dung +Vegetables	48.6 ± 2.3	25.7 ± 1.6	15.2 ± 1.9	3.5 ± 0.6	45.55 ± 2.96	31.7 ± 1.5*	0.35 ± 0.04
Dung +Barley Bran	45.6 ± 3.1	24.9 ± 2.4	15.7 ± 3.6	4.4 ± 0.4	45.04 ± 2.65	30.9 ± 1.5*	0.40 ± 0.03
Dung +Gram Bran	48.3 ± 3.2	24.8 ± 3.8	16.8 ± 2.5	0	63.38 ± 3.32	28.5 ± 1.2*	0.44 ± 0.06
Sheep							
Dung	# 48.2 ± 2.0	19.3 ± 3.9	11.5 ± 2.2	2.7 ± 0.2	# 42.66 ± 2.32	35.9 ± 0.2*	# 0.28 ± 0.03
Dung +Rice Bran	$ 46.1 ± 4.1	18.8 ± 4.4	09.9 ± 3.3	3.4 ± 0.3	45.75 ± 4.24	35.5 ± 1.1*	0.31 ± 0.02
Dung +Wheat Bran	45.4 ± 3.2	19.3 ± 1.4	13.2 ± 4.3	2.5 ± 1.2	46.45 ± 2.49	34.6 ± 1.8*	0.32 ± 0.05
Dung +Straw	46.7 ± 2.1	22.8 ± 1.8	13.1 ± 0.9	0	39.45 ± 4.85	33.5 ± 2.8*	0.34 ± 0.04
Dung +Vegetables	48.6 ± 5.3	23.0 ± 1.7	12.2 ± 0.8	3.4 ± 0.2	45.94 ± 4.66	33.6 ± 2.6*	0.30 ± 0.06
Dung +Barley Bran	45.6 ± 4.1	22.2 ± 2.3	14.2 ± 2.6	4.4 ± 0.4	39.42 ± 3.87	34.5 ± 2.8*	0.32 ± 0.03
Dung +Gram Bran	48.0 ± 3.2	22.8 ± 2.6	12.2 ± 1.4	0	50.32 ± 4.13	33.5 ± 2.1*	0.32 ± 0.02
Goat							
Dung	# 48.3 ± 2.3	23.0 ± 2.6	12.5 ± 1.3	2.4 ± 0.5	# 43.23 ± 3.64	34.5 ± 0.4*	# 0.29 ± 0.05
Dung +Rice Bran	$ 46.2 ± 4.2	23.3 ± 3.7	13.8 ± 2.4	2.5 ± 0.5	43.49 ± 4.14	32.8 ± 1.5*	0.30 ± 0.04
Dung +Wheat Bran	46.6 ± 3.2	21.8 ± 4.7	12.5 ± 0.9	3.2 ± 0.4	32.64 ± 4.43	39.6 ± 0.7*	0.30 ± 0.04
Dung +Straw	45.4 ± 5.2	21.6 ± 2.7	12.9 ± 1.8	0	42.32 ± 3.41	32.9 ± 1.1*	0.32 ± 0.02
Dung +Vegetables	47.7 ± 3.2	22.3 ± 2.5	13.4 ± 2.7	1.5 ± 0.8	46.82 ± 3.25	31.4 ± 2.9*	0.31 ± 0.04
Dung +Barley Bran	46.6 ± 2.4	22.9 ± 3.5	13.1 ± 1.5	4.3 ± 0.2	38.44 ± 5.53	30.2 ± 2.0*	0.34 ± 0.02
Dung +Gram Bran	51.3 ± 3.3	22.1 ± 4.5	12.3 ± 2.4	0	49.48 ± 4.44	30.7 ± 2.2*	0.30 ± 0.04
Horse							
Dung	# 47.3 ± 4.0	10.1 ± 2.3	21.2 ± 1.2	2.2 ± 0.5	# 48.54 ± 2.46	34.2 ± 1.2*	# 0.36 ± 0.02
Dung +Rice Bran	$ 50.5 ± 2.1	23.3 ± 2.7	13.3 ± 2.7	0	50.49 ± 3.68	32.4 ± 2.0*	0.37 ± 0.04
Dung +Wheat Bran	47.4 ± 3.2	22.1 ± 2.6	13.8 ± 1.8	0	50.54 ± 3.88	33.6 ± 0.4*	0.38 ± 0.06
Dung +Straw	48.6 ± 2.1	23.0 ± 4.6	15.2 ± 2.4	0	54.42 ± 4.54	32.8 ± 0.9*	0.39 ± 0.02
Dung +Vegetables	48.4 ± 1.3	23.3 ± 2.3	16.5 ± 2.4	3.4 ± 0.8	52.54 ± 2.50	30.4 ± 1.8*	0.34 ± 0.04
Dung +Barley Bran	45.5 ± 3.1	23.8 ± 3.4	15.2 ± 1.6	4.3 ± 0.3	49.56 ± 5.59	30.7 ± 2.0*	0.37 ± 0.03
Dung +Gram Bran	48.5 ± 3.2	23.1 ± 2.5	14.8 ± 1.6	0	65.53 ± 5.79	30.5 ± 2.0*	0.43 ± 0.02

Each value is the mean ± SE of 6 replicates. 2-way ANOVA: Significant ($P < 0.05$) $ within column, # within row.
* Significant ($P < 0.05$, *t*-test) between treated and control group.

worms (400 worms/kg vermicompost). At the same time, 1 litre fresh water was added to the drum and a container was placed below the drum tap. The aqueous VC extract (yellow-black) leaches out of the drum through the tap. After 1 to 2 days, the extraction process was complete.

Collection and preparation of biopesticide

1. Neem oil

Neem oil consisted of 0.03% azadirachtine, 90.57% neem oil, 5.00% hydroxy El, 0.50% epichlorohydrine, and 3.9% Aromax (Multiplex Agricare Pvt. Ltd., India).

2. Garlic extract

Aqueous extract of garlic was obtained from an *Allium sativum* bulb. A prepared aqueous extract (10 g/100 ml) (w/v) was mixed with diluted VW in a 1: 10 ratio.

3. Custard apple

Leaves were collected from the plant of custard apple (*Annona squamosa*). It is a native of South America and West Indies. A prepared aqueous extract (100 g/100 ml) (w/v) of leaves was mixed with diluted VW in a 1: 10 ratio.

Experimental setup for measurement of growth, observation of aphid, flowering period and productivity

Measurement of growth, number of aphids on the plant and productivity of crops were performed in the experimental field of vermiculture research centre, Department of Zoology, D.D.U. Gorakhpur University. The seeds of mustard were sowed directly in the cultivated soil. In the cultivated field, in a 1 m^2 (1 m × 1 m) area, 10 g of mustard seed were sown per square in equal amounta. Freshly extracted VW was diluted 7-fold with water. After 30 days VW was sprayed over the crops singly or in combination with different biopesticides. The control had no treatment of VW or biopesticides. Crop growth was measured by an auxanometer 50 days after the sowing date. The number of aphids was counted on each plant. The flowering period was observed in adult plants. After harvest of each crop, productivity was calculated as kg/m^2.

Statistical analysis

Values are expressed as the mean ± SE of 6 replicates. Two-way

analysis of variance (ANOVA) was applied to determined the significant ($P < 0.05$) difference among the number of aphids in the control and treated groups. One-way ANOVA was applied to assess significant ($P < 0.05$) differences between growth and productivity of crop with respect to different VW combinations. A student's *t*-test was also applied to analyze the significant ($P < 0.05$) differences between treated and control groups (Sokal and Rohlf 1973).

RESULTS

The combination of VW with BP viz. neem (*A. indica*) oil, aqueous extract of garlic (*A. sativum*) and leaf extracts of custard apple (*A. squamosa*) caused a significant ($P < 0.05$) reduction in pest infestation and increase in plant growth, early flowering and productivity of the mustard crop. A significant reduction in the aphid population was observed on plants treated with VW containing BP (**Tables 1-4**). Spraying VW obtained from different combinations of animal dung + agro-kitchen wastes with different plant products caused a time- and dose-dependent significant reduction of the aphid population on mustard plants. The third treatment (10 mg/m^2) of each combination caused maximum reduction in aphid numbers. The combination of VW with neem oil and garlic extract was highly effective against aphid (*L. erysimi*) after the third treatment and controlled approximately 95-97% of aphids (**Tables 2, 3**). The combination of VW with custard apple leaf extract also showed a significant reduction in aphid numbers after the third treatment (**Table 4**). The different combinations of garlic extract + VW and neem oil + VW of different animal dung + gram bran completely controlled aphid infestation on mustard plants (**Tables 2, 3**).

The growth of mustard plants in the control group was 31.60 cm 50 days after sowing. Three foliar sprays of VW obtained from different animal dung + agro-kitchen wastes with different BP significantly increased the growth of mustard plants. The highest growth of mustard (65.38 cm) was observed following a foliar spray of VW of buffalo dung + gram bran + neem oil, followed by VW of horse dung + gram bran and buffalo dung + gram bran with garlic extract (**Tables 2, 3**).

The flowering period of mustard in the control group was 52.4 days. Significantly early flowering was observed in all combinations of VW of different animal dung + agro-kitchen wastes singly, as well as in combination with different BP. The maximum significant early flowering periods of mustard were 28.5, 28.7 and 28.8 days shown in the

Table 3 Effect of vermiwash of different animal dung and agro / kitchen wastes (10 mg/m^2) with aqueous extract of garlic bulb (1:1) on aphid population as well as growth and productivity of mustard (*Brassica campestris*).

Vermiwash	No. of aphids				Growth of mustard (cm)	Flowering period (days)	Productivity (kg/m^2) after harvesting
	Before spraying	After first spraying	After second spraying	After third spraying	After 50 days		
Control	46.2 ± 4.4	67.4 ± 2.2	72.2 ± 5.8	83.5 ± 3.8	31.60 ± 2.56	52.4 ± 3.2	0.12 ± 0.02
Cow							
Dung	# 47.4 ± 3.3	23.3 ± 2.4	14.2 ± 1.2	0	# 42.97 ± 1.45	34.6 ± 2.4*	# 0.33 ± 0.03
Dung +Rice Bran	$ 45.3 ± 4.1	25.2 ± 3.4	15.2 ± 2.4	0	47.20 ± 2.16	33.4 ± 1.5*	0.34 ± 0.02
Dung +Wheat Bran	48.6 ± 5.2	24.7 ± 1.4	15.4 ± 2.4	1.6 ± 0.2	43.31 ± 1.53	33.6 ± 1.8*	0.34 ± 0.03
Dung +Straw	48.8 ± 6.1	26.6 ± 2.4	17.5 ± 0.4	2.2 ± 1.2	46.10 ± 4.43	34.8 ± 2.4*	0.35 ± 0.06
Dung +Vegetables	47.7 ± 4.2	25.1 ± 2.4	14.6 ± 1.3	3.5 ± 0.4	45.29 ± 3.53	34.2 ± 1.2*	0.33 ± 0.05
Dung +Barley Bran	48.9 ± 5.2	25.4 ± 1.5	17.2 ± 3.2	2.5 ± 1.1	46.08 ± 3.46	36.8 ± 1.4*	0.33 ± 0.02
Dung +Gram Bran	47.4 ± 2.1	25.9 ± 3.6	15.2 ± 1.8	0	43.29 ± 4.73	32.4 ± 2.7*	0.66 ± 0.03
Buffalo							
Dung	# 46.4 ± 2.3	22.2 ± 2.3	13.6 ± 1.4	0	# 49.17 ± 3.76	34.8 ± 2.4*	# 0.34 ± 0.05
Dung +Rice Bran	$ 47.5 ± 2.3	24.2 ± 1.2	16.6 ± 2.4	2.4 ± 0.3	52.23 ± 6.56	30.4 ± 2.6*	0.36 ± 0.08
Dung +Wheat Bran	46.6 ± 5.1	24.2 ± 1.4	15.6 ± 0.4	0	51.19 ± 5.84	31.3 ± 1.4*	0.36 ± 0.06
Dung +Straw	48.5 ± 4.2	24.2 ± 3.6	15.1 ± 1.3	1.4 ± 0.2	54.01 ± 5.49	32.3 ± 2.5*	0.40 ± 0.03
Dung +Vegetables	48.9 ± 2.1	25.7 ± 1.6	16.9 ± 0.9	0	50.25 ± 4.34	32.2 ± 2.4*	0.39 ± 0.04
Dung +Barley Bran	47.4 ± 9.2	25.8 ± 2.4	16.9 ± 0.6	3.2 ± 1.2	50.10 ± 4.52	31.5 ± 3.5*	0.42 ± 0.06
Dung +Gram Bran	48.4 ± 4.2	25.9 ± 2.5	14.3 ± 0.5	0	61.02 ± 4.28	28.8 ± 3.4*	0.45 ± 0.06
Sheep							
Dung	# 46.6 ± 2.3	19.3 ± 3.5	12.6 ± 1.6	0	# 36.32 ± 3.43	34.5 ± 2.5*	# 0.32 ± 0.04
Dung +Rice Bran	$ 47.2 ± 5.0	19.3 ± 1.2	10.8 ± 2.6	2.6 ± 1.2	43.11 ± 4.62	32.5 ± 2.8*	0.33 ± 0.02
Dung +Wheat Bran	46.3 ± 1.2	19.3 ± 2.4	14.6 ± 1.4	0	45.23 ± 4.05	32.6 ± 2.8*	0.32 ± 0.03
Dung +Straw	43.5 ± 2.2	22.8 ± 0.8	14.8 ± 0.6	1.4 ± 0.3	46.24 ± 3.15	32.2 ± 1.8*	0.35 ± 0.08
Dung +Vegetables	41.7 ± 4.1	24.0 ± 2.7	13.4 ± 0.8	3.5 ± 1.1	42.54 ± 6.48	31.8 ± 1.6*	0.34 ± 0.07
Dung +Barley Bran	42.6 ± 5.3	23.2 ± 2.6	15.8 ± 0.9	0	43.44 ± 5.27	30.5 ± 1.8*	0.34 ± 0.03
Dung +Gram Bran	42.9 ± 1.1	22.8 ± 0.6	13.6 ± 2.4	0	43.47 ± 4.44	29.7 ± 3.4*	0.35 ± 0.06
Goat							
Dung	# 42.5 ± 2.1	23.0 ± 1.6	13.5 ± 0.5	0	# 42.02 ± 2.33	34.6 ± 1.7*	# 0.32 ± 0.06
Dung +Rice Bran	$ 43.3 ± 5.1	23.3 ± 2.7	14.0 ± 2.3	2.2 ± 1.1	43.45 ± 3.25	32.8 ± 1.5*	0.33 ± 0.07
Dung +Wheat Bran	42.5 ± 1.3	22.8 ± 1.5	13.7 ± 0.6	0	34.78 ± 5.84	32.4 ± 2.4*	0.35 ± 0.05
Dung +Straw	42.6 ± 4.3	22.6 ± 1.7	13.8 ± 1.3	1.5 ± 0.4	36.75 ± 4.44	33.8 ± 2.4*	0.34 ± 0.05
Dung +Vegetables	40.3 ± 2.4	23.3 ± 1.5	14.2 ± 0.8	0	39.96 ± 6.65	33.2 ± 3.3*	0.36 ± 0.04
Dung +Barley Bran	40.8 ± 3.2	22.9 ± 1.4	14.8 ± 2.2	2.2 ± 0.2	42.58 ± 4.54	33.4 ± 3.4*	0.32 ± 0.06
Dung +Gram Bran	41.4 ± 2.0	23.4 ± 1.5	13.6 ± 0.9	0	49.58 ± 3.94	30.8 ± 2.8*	0.34 ± 0.05
Horse							
Dung	# 41.3 ± 1.3	21.9 ± 1.2	11.4 ± 1.3	0	# 50.54 ± 2.46	34.2 ± 2.5*	# 0.34 ± 0.06
Dung +Rice Bran	$ 42.4 ± 4.0	24.3 ± 2.7	14.8 ± 0.5	2.4 ± 0.5	53.73 ± 4.68	33.4 ± 2.4*	0.36 ± 0.06
Dung +Wheat Bran	41.3 ± 2.1	23.6 ± 2.6	14.3 ± 2.0	0	54.45 ± 5.88	32.9 ± 2.8*	0.35 ± 0.08
Dung +Straw	43.6 ± 5.2	24.2 ± 2.3	16.3 ± 0.6	1.5 ± 0.5	53.47 ± 2.54	31.2 ± 1.3*	0.36 ± 0.02
Dung +Vegetables	41.4 ± 4.1	24.3 ± 1.6	16.6 ± 1.2	0	55.56 ± 4.50	31.4 ± 2.8*	0.42 ± 0.03
Dung +Barley Bran	42.3 ± 5.3	24.8 ± 2.4	16.3 ± 0.9	0	52.78 ± 1.59	30.4 ± 1.4*	0.40 ± 0.03
Dung +Gram Bran	42.4 ± 1.1	24.1 ± 1.5	15.6 ± 1.3	0	56.53 ± 3.79	28.7 ± 2.5*	0.44 ± 0.05

Each value is the mean ± SE of 6 replicates. 2-way ANOVA: Significant ($P < 0.05$) $ within column, # within row.
* Significant ($P < 0.05$, *t*-test) between treated and control group.

Table 4 Effect of vermiwash of different animal dung and agro / kitchen wastes (10 mg/m^2) with leaf extract of custard apple (1:10) on aphid population as well as growth and productivity of mustard (*Brassica campestris*).

Vermiwash	No. of aphids				Growth of mustard (cm)	Flowering period (days)	Productivity (kg/m^2) after harvesting
	Before spraying	After first spraying	After second spraying	After third spraying	After 50 days		
Control	46.2 ± 4.4	67.4 ± 2.2	72.2 ± 5.8	83.5 ± 3.8	31.60 ± 2.56	52.4 ± 3.2	0.12 ± 0.02
Cow							
Dung	# 47.2 ± 0.3	20.8 ± 1.5	13.5 ± 1.4	5.1 ± 1.2	# 42.92 ± 1.75	34.0 ± 2.4*	# 0.23 ± 0.03
Dung +Rice Bran	$ 46.2 ± 0.2	30.2 ± 2.4	13.8 ± 2.4	6.2 ± 2.2	43.81 ± 2.47	33.2 ± 1.7*	0.25 ± 0.05
Dung +Wheat Bran	45.3 ± 0.3	22.6 ± 2.4	13.9 ± 1.4	7.1 ± 0.3	42.23 ± 3.48	32.4 ± 3.2*	0.26 ± 0.04
Dung +Straw	46.4 ± 0.2	23.3 ± 2.3	16.2 ± 2.4	8.2 ± 1.2	44.25 ± 3.24	32.4 ± 3.4*	0.25 ± 0.07
Dung +Vegetables	48.2 ± 0.3	25.4 ± 1.3	13.3 ± 1.4	5.3 ± 0.3	43.45 ± 2.28	31.4 ± 2.3*	0.28 ± 0.02
Dung +Barley Bran	47.4 ± 0.4	22.3 ± 3.4	15.5 ± 3.7	5.3 ± 2.1	43.46 ± 4.48	33.1 ± 2.4*	0.25 ± 0.04
Dung +Gram Bran	47.3 ± 0.3	23.3 ± 1.2	13.5 ± 2.2	8.5 ± 0.2	45.49 ± 1.17	32.4 ± 1.2*	0.27 ± 0.06
Buffalo							
Dung	# 46.2 ± 0.3	20.6 ± 1.2	10.8 ± 2.7	5.4 ± 0.4	# 49.62 ± 1.25	34.4 ± 3.4*	# 0.24 ± 0.04
Dung +Rice Bran	$ 47.3 ± 0.2	20.8 ± 1.2	14.3 ± 1.4	8.4 ± 1.2	52.85 ± 2.46	33.4 ± 2.3*	0.26 ± 0.02
Dung +Wheat Bran	46.4 ± 0.1	21.3 ± 2.4	13.6 ± 3.3	5.2 ± 0.5	53.75 ± 2.15	32.7 ± 2.6*	0.26 ± 0.07
Dung +Straw	48.6 ± 0.2	22.5 ± 1.8	13.7 ± 1.3	7.3 ± 1.4	51.86 ± 3.47	32.7 ± 1.4*	0.28 ± 0.04
Dung +Vegetables	47.3 ± 0.3	23.8 ± 3.4	14.7 ± 2.4	5.2 ± 0.4	54.13 ± 2.45	31.5 ± 1.8*	0.28 ± 0.07
Dung +Barley Bran	46.2 ± 0.3	23.2 ± 1.4	12.8 ± 1.4	6.2 ± 0.5	53.95 ± 1.27	32.7 ± 2.8*	0.28 ± 0.02
Dung +Gram Bran	46.5 ± 0.3	30.3 ± 1.4	16.4 ± 3.4	3.2 ± 0.4	59.95 ± 2.35	30.5 ± 2.1*	0.32 ± 0.04
Sheep							
Dung	# 46.0 ± 0.1	17.0 ± 2.7	11.5 ± 1.4	7.6 ± 1.3	# 43.42 ± 3.52	34.2 ± 2.4*	# 0.22 ± 0.07
Dung +Rice Bran	$ 47.3 ± 0.2	17.6 ± 2.4	10.4 ± 2.4	5.6 ± 0.3	44.62 ± 2.24	33.4 ± 4.1*	0.23 ± 0.04
Dung +Wheat Bran	46.4 ± 0.2	17.8 ± 2.2	12.9 ± 2.2	6.5 ± 0.7	44.83 ± 2.18	32.3 ± 2.4*	0.24 ± 0.05
Dung +Straw	47.2 ± 0.3	20.7 ± 3.5	11.8 ± 1.4	7.6 ± 0.8	50.74 ± 4.48	32.2 ± 2.5*	0.26 ± 0.04
Dung +Vegetables	46.5 ± 0.2	21.5 ± 1.7	12.5 ± 3.2	7.3 ± 0.4	49.95 ± 3.48	33.4 ± 2.7*	0.25 ± 0.02
Dung +Barley Bran	45.2 ± 0.1	20.7 ± 1.4	12.6 ± 1.4	7.3 ± 0.4	51.16 ± 3.47	32.2 ± 3.4*	0.23 ± 0.08
Dung +Gram Bran	47.6 ± 0.3	20.7 ± 2.4	11.3 ± 2.4	6.5 ± 1.2	52.12 ± 2.14	31.2 ± 2.4*	0.28 ± 0.04
Goat							
Dung	# 46.5 ± 0.3	21.9 ± 2.3	11.2 ± 2.2	7.8 ± 0.5	# 43.89 ± 2.82	34.1 ± 0.8*	# 0.23 ± 0.04
Dung +Rice Bran	$ 45.8 ± 0.2	21.5 ± 2.3	12.4 ± 1.4	7.5 ± 1.4	46.79 ± 3.42	34.2 ± 2.7*	0.25 ± 0.04
Dung +Wheat Bran	46.6 ± 0.1	20.3 ± 0.6	11.3 ± 2.2	6.5 ± 0.4	46.89 ± 3.22	33.0 ± 0.4*	0.26 ± 0.05
Dung +Straw	47.6 ± 0.2	20.2 ± 1.4	10.2 ± 2.2	6.7 ± 0.6	46.56 ± 2.42	32.4 ± 2.1*	0.28 ± 0.04
Dung +Vegetables	47.4 ± 0.1	21.4 ± 1.4	12.2 ± 3.2	6.5 ± 0.8	49.24 ± 4.45	32.3 ± 2.8*	0.24 ± 0.02
Dung +Barley Bran	48.4 ± 0.2	20.5 ± 2.4	11.4 ± 1.2	6.7 ± 0.7	44.28 ± 3.12	31.4 ± 2.2*	0.24 ± 0.05
Dung +Gram Bran	48.6 ± 0.2	21.2 ± 3.2	11.3 ± 2.1	5.8 ± 1.4	51.98 ± 2.43	31.1 ± 3.2*	0.25 ± 0.04
Horse							
Dung	# 48.4 ± 0.2	19.7 ± 2.2	10.3 ± 2.4	8.7 ± 2.6	# 52.23 ± 2.12	34.4 ± 1.5*	# 0.28 ± 0.03
Dung +Rice Bran	$ 47.8 ± 0.3	21.5 ± 1.5	13.5 ± 1.2	5.7 ± 1.4	54.12 ± 3.14	32.0 ± 2.5*	0.30 ± 0.04
Dung +Wheat Bran	46.4 ± 0.2	21.2 ± 2.1	13.3 ± 1.5	5.6 ± 0.6	32.95 ± 2.45	33.3 ± 0.7*	0.34 ± 0.04
Dung +Straw	47.6 ± 0.2	22.2 ± 2.4	14.2 ± 2.2	7.5 ± 0.7	56.90 ± 3.14	30.2 ± 0.5*	0.36 ± 0.02
Dung +Vegetables	48.7 ± 0.2	21.8 ± 1.1	16.2 ± 2.3	5.7 ± 1.8	53.96 ± 2.47	30.2 ± 2.4*	0.35 ± 0.04
Dung +Barley Bran	46.6 ± 0.2	21.6 ± 2.2	16.9 ± 2.4	7.5 ± 0.7	52.95 ± 3.41	31.4 ± 2.4*	0.44 ± 0.04
Dung +Gram Bran	47.2 ± 0.6	21.5 ± 2.1	16.3 ± 3.4	6.5 ± 0.9	58.37 ± 1.45	30.2 ± 3.1*	0.37 ± 0.06

Each value is the mean ± SE of 6 replicates. 2-way ANOVA: Significant ($P < 0.05$) $ within column, # within row.
* Significant ($P < 0.05$, *t*-test) between treated and control group.

buffalo dung + gram bran/horse dung + gram bran with neem oil/garlic extract VW combinations (**Tables 2, 3**).

A significant increase in productivity of mustard was observed in all combinations of VW of different animal, agro-kitchen wastes singly and in combination with neem oil, garlic extract and leaf extract of *A. squamosa*. The combinations of buffalo dung +gram bran with aqueous extract of garlic bulb resulted in maximum productivity of mustard in comparison with all biopesticides (**Tables 2, 3**).

DISCUSSION

It is clear from our results that the use of VW extracted from VC obtained from different combinations of animal and agro-kitchen wastes singly as well as in combination with different BP like neem (*A. indica*) oil, aqueous extract of garlic (*A. sativum*) bulb and leaf extract of custard apple (*A. squamosa*) (Epino and Saxena 1982; Mariappan *et al.* 1982; Gupta and Sharma 1993; Pavela *et al.* 2004; Gambola-Leon *et al.* 2006) caused a significant reduction in the aphid population; aphids are an economically harmful insect pest to various agricultural crops. Such control of the aphid population ultimately enhanced the growth, early flowering and productivity of mustard crop. VW of different animal and agro-wastes have a significant amount of nitrogen, phosphorus, Ca^{++}, K^{+} vitamins, enzyme, plant growth regulators, etc. (Kaushik and Garg 2003; Pathak and Ram 2004; Suthar 2008; Nath and Singh 2009; Nath *et al.* 2009a) and plant pesticides viz. neem oil, aqueous extract of garlic bulb and leaf extract of custard apple have a toxic effect against aphid infestation (Koul 1999; Pavela and Barnet 2004; Pavela *et al.* 2004). Hossain and Poehling (2006) reported that the neem-based insecticide Azal-T/S^{R} was effective against different immature life stages of Asian leafminer *Liriomyza sativae* (Diptera: Agromyzidae) on tomato. The application of different neem products was effective against various rice, wheat, pulse and vegetable pests (Prakash *et al.* 2008). Epino and Saxena (1982) reported that use of leaves and fruit extracts of custard apple was effective against the green leaf hopper (*Nephottetix virescens*) and brown plant hopper (*Nilaparvata lugens*). The volatiles of neem seed kernel prevent the contact and repel the moth of *Helicoverpa armigera.* Azadirachtin reduces the feeding rate of the larvae of various insect pests (Vatandoost *et al.* 2001; Weathersbee and Mekeenzie 2005).

VW extracted from VC obtained from different animal agro-kitchen wastes with garlic extract/neem oil completely controlled aphid infestation on mustard plants. The reduc-

tion of aphid infestation may be due to the mortality of aphids from plants. The chemical content found in the plant extract had the ability to cause aphid mortality (Vatandoost *et al.* 2001; Weathersbee and Mekeenzie 2005). The highest growth of mustard plants was observed by the spray of VW obtained from buffalo dung + gram bran in all combinations with biopesticides. The VW of these combinations are a rich source of enzyme, vitamins, and plant growth regulators such as IAA (indole-3-acetic acid), gibberellin, cytokinine along with micro- and macronutrients which enhance plant growth (Pathak and Ram 2004).

There was significant reduction in flowering period of mustard in all combinations of VW of different animal and agro-wastes + neem oil/garlic bulb extract/custard apple extract with respect to the control. The combination of VW with biopesticide caused early flowering of mustard plants, possibly due to the presence of TKN and TP in the VW which stimulates the early flowering of crops (Atiyeh *et al.* 2001, 2002; Nath and Singh 2009; Nath *et al.* 2009a, 2009b). The rich amount of TKN and TP stimulate the early flowering period of *Daucus carota* and mustard (Muscolo *et al.* 1999; Anburani *et al.* 2003; Pal and Shambhi 2003). Ali and Jahan (2001) found a similar result by using lady's finger (*Ablemoschus esculentus*) VC.

The combination of buffalo dung + gram bran with an aqueous extract of garlic bulb and neem oil showed significant maximum productivity of mustard plants due to the presence of essential nutrients in VW which increased the metabolic activity of plants as well as garlic bulb extract/ neem oil which reduced the aphid infestation of mustard plant (Ali and Jahan 2001; Gareth *et al.* 2006). Large amount of humic acid were produced during vermicomposting which lowers the pH of soil and ultimately affect the productivity of plant (Gupta 2005). Reduction of aphid on plants directly affects the productivity of crops (Akhtar and Mahamood 2004; Musabyimana and Saxena 2008). Buckerfield *et al.* (1999) reported that the continuous application of VW promotes early flowering and better productivity of radish.

CONCLUSION

Different combinations of VW obtained from buffalo dung + gram bran with neem oil and aqueous extract of garlic are effective for controlling aphid infestation on mustard plants. They also increases the growth, induce early flowering and enhance the productivity of mustard up to 3.5-fold with respect to the control. The uses of each combination of VW and biopesticide are easily produced, biodegradable and cheap. These products could be ecologically safe and hence acceptable among farmers.

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