ies, because of high frequency of plant conversion, etc. The frequency of somatic embryogenesis in the present study was found to be the result of interaction between genotype and the type and concentration of auxin used. Parrott *et al.*[19] found that the genotype had a significant effect on the ability of immature soybean cotyledons to undergo the auxin-stimulated somatic embryogenesis.

In conclusion, an efficient protocol was developed for high frequency somatic embryogenesis using a simple medium. The present protocol has a distinct advantage over the earlier published protocols, the explant is hypocotyl by germinating seeds, which is available throughout the year.

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Influence of metalaxyl on *Glomus fasciculatum* associated with wheat (*Triticum aestivum* L.)

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Soil incorporation of metalaxyl [methyl *N*-(2-methoxyacetyl)-*N*-(2,6,xylyl)-DL-alaninate] significantly enhanced root colonization of the vesicular-arbuscular (VA) mycorrhizal fungi *Glomus fasciculatum* associated with wheat. The stimulatory response of VA mycorrhizal fungi to low concentration of metalaxyl resulted in increased plant biomass production, nutrient uptake and grain yield of wheat. However, higher concentrations of metalaxyl, particularly 2.5 ppm of metalaxyl affected the mycorrhizal infection and seed yield of wheat. Addition of urban compost to an extent ameliorated the toxic effect of fungicide on VA mycorrhizal colonization, plant growth and yield of wheat when compared to unamended soil.

THE role of agro-chemicals on vesicular-arbuscular mycorrhizal development and efficiency requires better understanding because mycorrhizal fungi are necessary components of most plant systems, and have significant effect on plant growth, physiology and nutrition. Several workers[1-3] have reported the adverse effect of systemic and nonsystemic fungicides to VA mycorrhizae. Recently, considerable attention has been given to a systemic fungicide metalaxyl [methyl *N*-(2-methoxyacetyl)-

Table 1. Effect of metalaxyl on per cent mycorrhizal colonization of wheat

Treatments	Fungicide dose (ppm)	Days after planting: 40	80	120	Mean
Without compost	Control	18.00	45.00	64.00	42.33
	0.5	21.00	52.00	69.00	47.33
	1.0	26.00	38.00	76.00	46.67
	2.5	12.00	25.00	43.00	26.67
	Mean	19.25	40.00	63.00	40.75
With compost	Control	29.00	58.00	73.00	53.33
	0.5	28.00	49.00	78.00	51.67
	1.0	16.00	63.00	70.00	49.67
	2.5	22.00	31.00	42.00	31.67
	Mean	23.75	50.25	65.75	46.58
		SEm±		LSD (0.05)	
	Stages	2.4688		6.8431	
	Compost	2.0158		5.5874	
	Treatments	2.8507		7.9018	

Table 2. Effect of metalaxyl on dry matter production (g $plant^{-1}$) of wheat

Treatments	Fungicide dose (ppm)	Shoot Days after planting 40	80	120	Mean	Root Days after planting 40	80	120	Mean
	Control	0.440	2.884	4.336	2.553	0.154	0.306	0.842	0.434
Without compost	0.5	0.490	3.161	5.318	2.989	0.158	0.311	0.777	0.415
	1.0	0.360	1.818	3.460	1.879	0.124	0.259	0.708	0.363
	2.5	0.383	1.282	3.512	1.725	0.128	0.241	0.656	0.341
	Mean	0.418	2.286	4.156	2.286	0.141	0.279	0.745	0.388
	Control	0.548	2.642	6.081	3.090	0.177	0.355	1.587	0.706
With compost	0.5	0.543	2.498	5.511	2.850	0.161	0.377	1.247	0.595
	1.0	0.478	2.256	6.031	2.921	0.148	0.230	1.215	0.531
	2.5	0.420	1.550	2.333	1.434	0.130	0.238	0.524	0.297
	Mean	0.497	2.236	4.989	2.573	0.154	0.300	1.143	0.532

	Shoot SEm±	Shoot LSD (0.05)	Root SEm±	Root LSD (0.05)
Stages	0.0844	0.2341	0.0087	0.0240
Compost	0.0690	0.1911	0.0071	0.0196
Treatments	0.0975	0.2703	0.0100	0.0277

N-(2,6,xylyl)-DL alaninate] and its influence on VA mycorrhizal colonization. Metalaxyl is an acylalanine fungicide that controls root rot incited by Oomycetes of the order Peronosporales. Soil incorporation of metalaxyl has been reported to increase VA mycorrhizal colonization in some of the economically important crops[4–6]. The present experiment was carried out to evaluate the effect of different concentrations of metalaxyl on VA mycorrhizal colonization, plant growth and yield of wheat.

Sandy loam soil was collected from an uncropped grassy area of the Indian Agricultural Research Institute farm, New Delhi, and passed through a 2 mm sieve. The preliminary analysis of the soil used showed 0.18% organic carbon, 0.026% total nitrogen, 3.2 kg ha^{-1} available phosphorus, 140 kg ha^{-1} available potash and the pH was 7.2. Metalaxyl was obtained from Ciba-Geigy, Switzerland. The soil was treated with 0.5 ppm, 1.0 ppm and 2.5 ppm of metalaxyl prior to sowing. Soil amendment was done with 1% urban compost to mitigate the deleterious effect of fungicide. Urban compost was obtained from the mechanical compost plant, Okhla, Delhi. The proximate analysis of urban compost is given as follows: Organic carbon 16.86%, total nitrogen 0.42%, available phosphorus 0.037%, water holding capacity 82.73% and the pH 8.10.

Seeds of wheat (*Triticum aestivum* L.) cultivar HD-2428 and culture of VA-mycorrhizae *Glomus fasciculatum* were obtained from the Cereal Laboratory and the Division of Microbiology, IARI, New Delhi, respectively. Plants were grown in earthen pots (13″ × 12″) containing 10 kg of ground and sieved soil. Undamaged, healthy and uniform seeds were surface sterilized by rinsing in 95% ethanol in a clean sterile beaker for one min, followed by immersion in 0.2% acidified $HgCl_2$ for 5 min and washed in several changes of sterile distilled water.

The VA mycorrhizal fungus was inoculated by the layering method[7]. The inoculum consisting of ground and dried sand: soil mixture containing infected root segments and chalamydospores were used at the rate of 100 g pot^{-1}. The inoculum was placed in layers or pads at a depth of 3.5 cm from the top, over which a thin layer of soil was spread. Holes were made to dibble the seeds. Before dibbling the seeds, small quantity of VA mycorrhizal inoculum was added beneath the seeds so as to enable the inoculum to come in contact with emerging roots. The plants were watered on alternate days to near-field capacity. Inoculated controls were maintained without fungicide. The plants were harvested after 40, 80 and 120 days of growth. At each harvest, per cent mycorrizal infection, dry weight of shoots and roots were recorded and the representative samples were analysed for N and P. The concentration of P was estimated by the vanadomolybdate method after digestion with tri acid mixture. Similarly, the nitrogen content was determined by the kjeldahl method[8]. After harvesting, part of the root system was cleared and stained[9] and the per cent mycorrhizal colonization was assessed and calculated from the frequency distribution method[10].

The present investigation revealed that low concentration of metalaxyl resulted in an increased mycorrhizal colonization of wheat roots at all the stages of observation (Table 1). Previous studies reported[5,11] that use of metalaxyl at recommended field rates either increased or had no adverse effect on mycorrhizal colonization associated with maize and sorghum respectively. Though the precise mechanisms by which the fungicide stimulates the VA mycorrhizal fungi are unknown[12], probably

Table 3. Effect of metalaxyl on grain yield, nitrogen and phosphorus[3] uptake (g plant^{-1}) at harvesting stage of wheat

Treatments	Fungicide dose (ppm)	Grain yield	N uptake	P uptake
Without compost	Control	8.690	0.164	0.045
	0.5	9.050	0.160	0.046
	1.0	5.280	0.087	0.022
	2.5	5.230	0.085	0.027
With compost	Control	9.560	0.201	0.055
	0.5	9.010	0.200	0.060
	1.0	8.390	0.180	0.049
	2.5	5.450	0.082	0.030
	SEm±	0.0160	0.0003	0.0002
	LSD (0.05)	0.0460	0.0010	0.0006

metalaxyl enhances the VA mycorrhizal infection by reducing the population of plant pathogens and also other soil microbes which are responsible for suppression of root colonization, thus allowing greater invasion of roots by VA mycorrhizal fungi[13,14].

The stimulatory response of VA mycorrhizal fungi to low concentration of metalaxyl resulted in the increase in biomass (Table 2), nutrient uptake and grain yield of wheat (Table 3). Similarly Afek *et al.*[15] observed an increased VA mycorrhizal colonization of roots and plant biomass in the presence of metalaxyl. The primary mechanism which is responsible for stimulation of plant growth by VA mycorrhizal fungi is due to increased uptake of phosphorus and other nutrients. The possibility of plant growth harmones being involved in such a response has also been suggested[16]. Further, Barea and Azcon-aguilar[17] observed the substances with the properties of gibberellic acid and cytokinin in the extract of *Glomus mosseae* culture.

The reduction of VA mycorrhizal infection and plant growth at higher level of metalaxyl were attributed to suppression of the mycorrhizal fungus by the fungicide. Jabaji Hare and Kendrick[12] have reported the inhibition of mycorrhizal colonization of leek roots by metalaxyl and also the fungicide significantly decreased growth of plants with time. The effect of metalaxyl on mycorrhizal infection may be a direct action or mediated through phytotoxic effect on root function and growth. In an experiment[18], application of metalaxyl at a rate of 200 µl/l reduced the plant biomass of prairie grass in steamed and nonsterile soils, the results indicated that higher level of fungicide application was phytotoxic. It was observed that the amendment of one per cent urban compost to an extent ameliorated the toxic effect of metalaxyl on VA mycorrhizal infection, plant growth, nutrient uptake and yield of wheat when compared to unamended soils. Schiavon *et al.*[19] and Stearman *et al.*[20] reported that organic matter reduces the phytotoxicity of agro-chemicals, whereas fulvic acid and humin helps in detoxification through formation of low energy bonds. Further, organic matter provides more sites for adsorption to the pesticides, thus reducing its amount in soil solution and protecting microorganisms from the toxic effects.

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