

**Vermiculture Can Promote Sustainable Agriculture and Completely Replace Chemical Agriculture: Some Experimental Evidences by Studies on Potted and Farmed Cereal and Vegetable Crops**

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## Vermiculture Can Promote Sustainable Agriculture and Completely Replace Chemical Agriculture: Some Experimental Evidences by Studies on Potted and Farmed Cereal and Vegetable Crops

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**Key words:** Vermicompost nutritionally superior to conventional composts . vermicompost excel chemical fertilizers in plant growth promotion and productivity . continued application of vermicompost increases yield with reduced use of vermicompost

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### INTRODUCTION: THE SCIENTIFIC EVIDENCE OF THE POTENTIAL OF VERMICOMPOST TO REPLACE CHEMICAL FERTILIZERS

Experimental studies on the agronomic impacts of earthworms & its vermicompost on crop plants all over the world is conclusively proving that their application in farm soil over subsequent years can lead to enhanced production of 'safe food', both in 'quantity & quality' without recourse to agro-chemicals. Several scientists working on vermiculture throughout the world have confirmed the positive role of earthworms and its metabolic products (vermicast) on crop growth and development. Important among them are Alam (6); Ansari (8); Atiyeh (17 & 18); Arancon (11; 12 & 13); Bhat & Khambata (24); Bhatia (26 & 27); Baker & Barrett (28); Buckerfield (48); Chauhan (51); Canellas (49); Edwards & Burrows (70); Ghabbour, (87); Garg & Bhardwaj (84); Krishnamoorthy & Vajranabhaiah (115); Palanisamy (133); Pajon (132); Reddy (144); Scheu (154); Singh (168); Sharma (161); Suhane (183); Spain (178); Sukumaran (184); Tomar (194); Valani (203); Wilson & Carlie (210); and Webster (206).

Our studies on vegetable and cereal crops done in India at University of Rajasthan (1997-2001) & at Bihar Agriculture University (2007-2009) and in Australia at Griffith University (2007-2009), has also testified and strengthened the views of other workers. Application of vermicompost in potted and field crops displayed excellent growth performances in terms of height of plants, color & texture of leaves, appearance of fruiting structures etc. as compared to chemical fertilizers and the conventional compost. There is also less incidences of pest & disease attack & reduced demand of water for irrigation.

### SOME EXPERIMENTAL STUDIES TESTIFYING THE AGRONOMIC VALUE OF VERMICOMPOST AS SUPERIOR TO CONVENTIONAL COMPOST AND A SUSTAINABLE ALTERNATIVE TO CHEMICAL FERTILIZERS

#### (A) Studies on potted cereal & vegetable crops

**(1) Agronomic impact studies of earthworms and vermicompost vis-a-vis conventional cattle dung compost and chemical fertilizers on potted vegetable crops (University of Rajasthan, Jaipur, India, 1997-99):** Agarwal (4) studied this for Ph. D program on potted egg plant (*Solanum melongena*) and okra (*Abelmoschus esculentus*). There were three (3) treatments with five (5) replicas of each and a control. About 8 kg of near neutral soil devoid of any organic matter was used in each pot. 250 gm of vermicompost was used. It was prepared indigenously by mixed species of earthworms *Eisinea fetida*, *Perionyx excavatus* & *Eudrilus euginae* feeding on kitchen waste and cattle dung. Chemical fertilizers were used as urea for nitrogen (N =1.40 gm), single super phosphate (P = 2.50 gm) and murate of potash (K = 1.04 gm). While vermicompost was applied only once, chemicals were applied three times during the period of growth & maturation. Results are given in Tables 1 and 2

**Important observations and findings:** Potted egg-plants grown on vermicompost with live earthworms in soil bored on average 20 fruits/plant with average weight being 675 gm. Whereas, those grown on chemical fertilizers (NPK) bored only 14 fruits/plant with average weight being only 500 gm. Total numbers of fruits obtained from vermicompost (with worms) applied plants were 100 with maximum weight being 900 gm while those on chemicals were 70 fruits and 625 gm as maximum weight of a fruit. Interestingly, egg-plants grown on exclusive vermicompost (without worms) did not perform as with those with worms, but were significantly better over those on chemical fertilizers.

Table 1: Agronomic impacts of vermicompost, earthworms and vermicompost vis-a-vis chemical fertilizer on growth and development of potted egg plants

Treatments	Av. vegetative growth (in inches)	Av. No. of fruits/plant	Av. Wt. of fruits/plant	Total No. of fruits	Max. Wt. of one fruit
1 Earthworms (50) +Vermicompost (250 gm)	28	20	675 gm	100	900 gm
2 Vermicompost (250 gm)	23	15	525 gm	75	700 gm
3 Chemical Fertilizer (NPK) (Full dose)	18	14	500 gm	70	625 gm
4 CONTROL	16	10	425 gm	50	550 gm

(N.B. Value of vegetative growth was taken that was achieved on the 90th day of the study, while the fruiting was estimated from the 45th day & ending with over 120 days)

Source: Agarwal (1999); Ph.D Thesis; University of Rajasthan, Jaipur, India

Table 2: Agronomic impacts of vermicompost, worms with vermicompost vis-a-vis chemical fertilizer on growth and development of potted okra plants

Treatment	Av. vegetative growth (in inches)	Av. No. of fruits/plant	Av. Wt. of fruits/plant	Total No. of fruits	Max. Wt. of one fruit
1 Earthworms (50) + Vermicompost (250 gm)	39.4	45	48 gm	225	70 gm
2 Vermicompost (250 gm)	29.6	36	42 gm	180	62 gm
3 Chemical Fertilizer (NPK) (Full dose)	29.1	24	40 gm	125	48 gm
4 Control	25.6	22	32 gm	110	43 gm

(N.B. Value of vegetative growth was taken that was achieved on the 90th day of the study, while the fruiting was estimated after 45th day and ending with over 120 days.)

Source: Agarwal (1999); Ph.D Thesis; University of Rajasthan, Jaipur, India

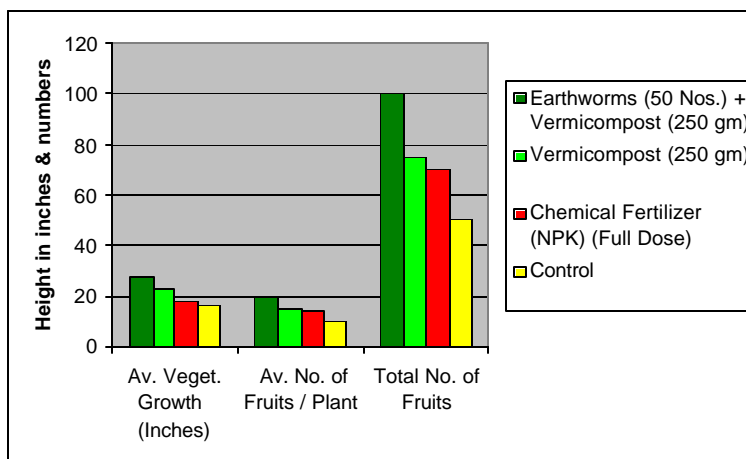


Fig. 1: Graph showing growth & development of egg plants promoted by vermicompost with earthworms, only vermicompost and those by chemical fertilizers

**Important observations and findings:** Potted okra plants grown on vermicompost (with live worms in soil) bore on average 45 fruits/plant with average weight being 48 gm. Whereas, those grown on chemical fertilizers (NPK) bore only 24 fruits/plant with average weight being only 40 gm. Total numbers of fruits obtained from vermicompost (with worms) applied plants were 225 with maximum weight being 70 gm while those on

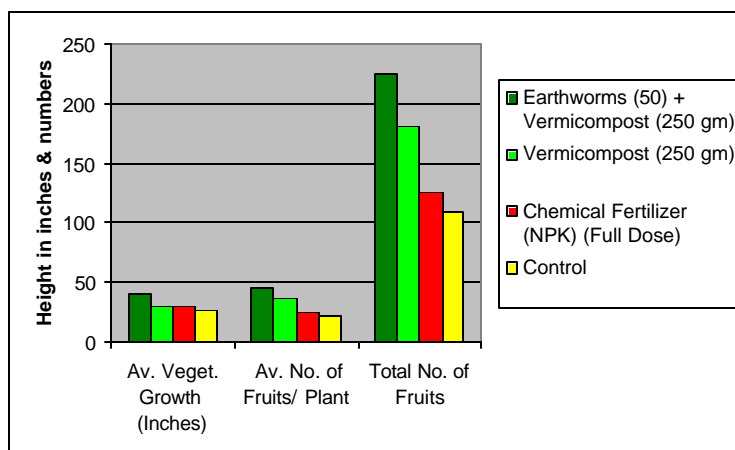


Fig. 2: Graph showing growth & development of okra plants promoted by vermicompost with earthworms, only vermicompost and those by chemical fertilizers

chemicals were 125 fruits and 48 gm as maximum weight of a fruit. Again, okra plants grown on exclusive vermicompost (without worms) did not perform as with those with worms, but were significantly better over those on chemical fertilizers.

## DISCUSSION

Both vegetable crops performed exceedingly well when 'live earthworms' were present along with its vermicompost. They made excellent impact on 'fruit development' justifying the beliefs of Surpala (150). Vermicompost when used alone also promoted good growth but not as much when worms were themselves present in soil in significant numbers. Both were significantly better over chemical fertilizers. Another significant finding was the 'less incidence of pest and disease attack', better taste of fruits of vegetable crops grown with earthworms and vermicompost alone or together.

**(2) Agronomic Impact Studies of Earthworms & Vermicompost Vis-a-vis Conventional Cattle Dung Compost & Chemical Fertilizers on Potted Wheat Crops (University of Rajasthan, Jaipur, India, 2000-03):** Bhatia (26) studied it for Ph. D program. Three (3) treatments with four (4) replicas of each were prepared and one kept as control. About 8 kg near neutral soil devoid of any organic matter was used in each pot. 250 gm of vermicompost and same amount of cattle dung compost was used. Compost was obtained from local farmer. Vermicompost was prepared indigenously by mixed species of earthworms *E. fetida*, *P. excavatus* & *E. euginae* feeding on kitchen waste and cattle dung. Chemical fertilizers were used as urea for nitrogen (N =1.40 gm), single super phosphate (P = 2.50 gm) and murate of potash (K = 1.04 gm). While vermicompost and cattle dung compost was applied only once, chemicals were applied three times during the period of growth & maturation. Results are given in Table 3.

**Important observations, findings and discussion:** The potted wheat crops with 'earthworms & vermicompost' made excellent progress from the very beginning of seed germination up to maturation. They were most healthy and green, leaves were broader, shoots were thicker and the fruiting ears were much broader and longer with average greater number of seed grains per ear. Significantly, they were much better (nearly two-fold in growth & bore over 55% more seed grains) over those grown on chemical fertilizers. Although the wheat crops grown on cattle dung compost were very close to those on chemical fertilizers but could not catch up with vermicompost. This conclusively proves that vermicompost store and retains more nutrients (and too in plant-available forms), have more beneficial microbes and other growth promoting factors than the conventional compost over a period of time.

Table 3: Agronomic impacts of earthworms and vermicompost vis-a-vis cattle dung compost and chemical fertilizers on growth and yield of potted wheat crops

Parameters studied	Control	Treatment-1 earthworms and vermicompost	Treatment-2 chemical fertilizer	Treatment-3 cattle dung compost
1 Number of seed germinated out of 100	50.00	90.00	60.00	56.0
2 Total height of plant (Av. cm)	34.16	85.22	39.97	37.3
3 Ear length (Av. Cm)	4.82	8.77	5.45	5.1
4 Number of seed grains per ear (Av. Nos.)	11.80	31.10	19.90	17.4
5 Number of tillers per plant	1.00	2-30	1-20	1-2

Source: Bhatia (2000); Ph.D Thesis, University of Rajasthan, Jaipur, India

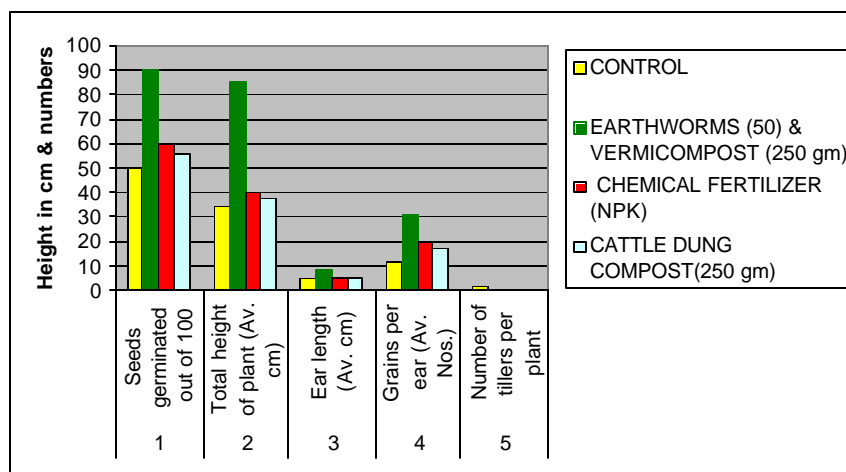


Fig. 3: Graph showing growth & yield of potted wheat crops promoted by earthworms & vermicompost, conventional cattle dung compost & chemical fertilizers

Table 4: Agronomic impacts of earthworms (with feed), vermicompost vis-a-vis conventional compost on growth and development of potted corn crops (average growth in cm)

Parameters studied	Treatment-1 earthworms (25) with feed (400 gm)	Treatment-2 conventional compost (400 gm)	Treatment-3 vermicompost (400 gm)
Seed sowing	9 <sup>th</sup> Sept. 2007	Do	Do
Seed germination	5 <sup>th</sup> Day	6 <sup>th</sup> Day	5 <sup>th</sup> Day
Avg. growth in 3 wks	41	42	53
Avg. growth in 4 wks	49	57	76
App. of male rep. organ (in wk 6)	None	None	Male Rep. Organ
Avg. growth in 6 wks	57	70	104
Avg. growth in 9 wks	64	72.5	120
App. of female rep. organ (in wk 10)	None	None	Female Rep. Organ
App. of new corn (in wk 11)	None	None	New Corn
Avg. growth in 14 wks	82	78	135
Color & texture of leaves	Green & thick	Light green & thin	Deep green, stout, thick & broad leaves

Source: Sinha & Bharambe (2007); Griffith University, Australia

**3) Agronomic Impacts Studies of Earthworms & Vermicompost Vis-à-vis Conventional Compost on Potted Corn Crops (Griffith University, Brisbane, Australia, 2006-07):** This study was designed to test the growth promoting capabilities of earthworms added with ‘feed materials’ and ‘vermicompost’, as compared to ‘conventional compost’. Vermicompost was prepared indigenously by degrading food & garden wastes by earthworms *Eisinia fetida*. Conventional compost was obtained from local nursery. It had three (3) treatments with three (3) replicas of each. Crushed dry leaves (400 gm) were used as feed materials. Results are given in Table 4.

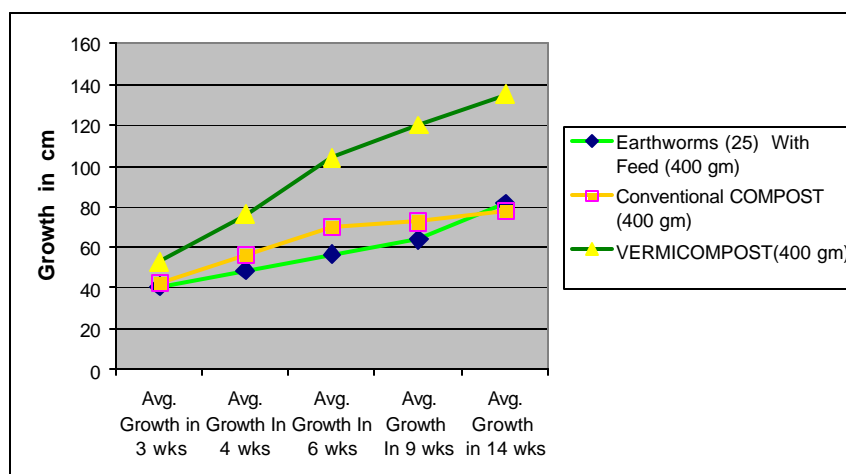


Fig. 4: Graph showing growth performances of corn plants influenced by earthworms (with feed), vermicompost and conventional compost in 14 weeks period

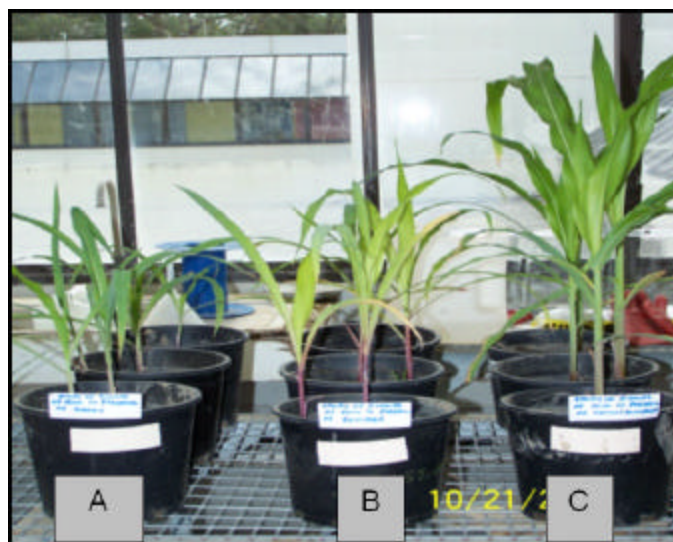


Photo showing growth of corn plants after 6 weeks

Keys: (A)-Corn plants with EARTHWORMS (50 Nos.) & FEED MATERIALS (400 gm) → 57 cm  
 (B)-Plants with CONVENTIONAL COMPOST (400 gm) in soil → 70 cm  
 (C)-Plants with VERMICOMPOST (400 gm) in soil → 104 cm

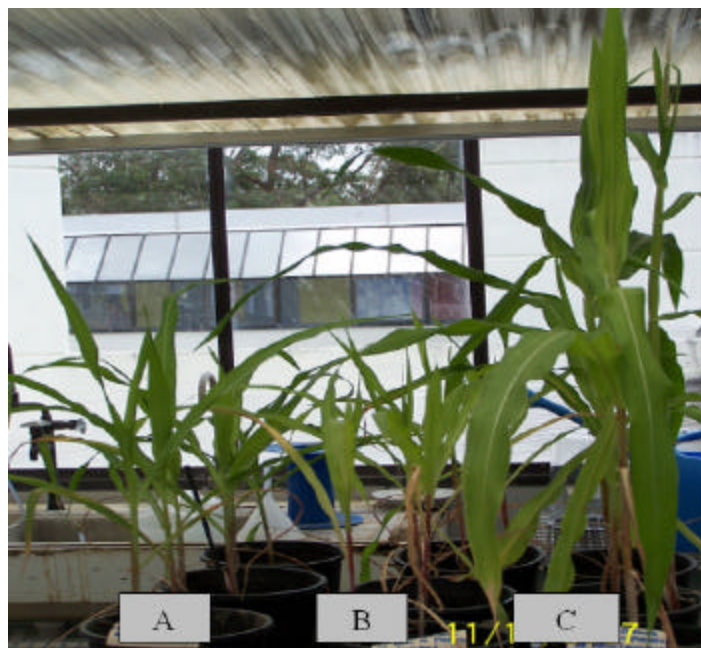


Photo showing growth of corn crops after 14 weeks

Keys: (A)-Corn plants with EARTHWORMS (50) & FEED (400 gm) in soil → 82 cm

(B)-Plants with CONVENTIONAL COMPOST (400 gm) in soil → 78 cm

(C)-Plants with VERMICOMPOST (400 gm) in soil (App. of MALE & FEMALE reproductive organs & the NEW CORN) → 135 cm

**Important observations, findings and discussion:** Corn plants with vermicompost in soil (Pot C) achieved rapid and excellent growth and attained maturity (appearance of male & female reproductive organs) very fast. Plants on conventional compost (Pot B) could not achieve maturity until the period of study (week 14). Plants with worms provided with 'feed materials' (Pot A) performed better than those on conventional compost (Pot B) at the completion of study (Week 14). It infers that worms need sufficient 'organic residues' in soil to feed upon and convert into vermicast which works as 'storehouse' of nutrients and the growth promoting biochemical factors.

**4) Agronomic Impact Studies of Vermicompost Vis-a-vis Conventional Compost & Chemical Fertilizers on Potted Wheat Crops (Griffith University, Brisbane, Australia, 2008):** Chauhan (51) studied it as a part of 40 CP honours project. It was designed to compare the growth promoting abilities of vermicompost & earthworms with conventional compost (composted cow manure) & chemical fertilizers on wheat crops. About 7 kg of near neutral soil devoid of organic matter was used. It had three (3) treatments with two (2) replicas of each and a control. Treatment 1 was with chemical fertilizers (NPK + Mg+S+Fe+B+Zn), Treatment 2 with composted cow manure and Treatment 3 with vermicompost and earthworms. Chemical fertilizer (supplied by Brunnings, Australia) & composted cow manure (produced by Kriedemann Company, Australia) were bought from nursery. Vermicompost was prepared by composting MSW (food and garden wastes) by *Eisinea fetida*. Five (5) gm of chemicals was applied in three (3) doses at three different times of growing period-first at the time of seed sowing, second after a month and the third after another month. It had total nitrogen (N) 14.8%, total phosphorus (P) 4.3% and potassium (K) as potassium sulphates 12.5%. Fifty (50) earthworms & 500 gm of vermicompost and same amount of composted cow manure were applied only once at the time of seed sowing. 5 x 3 gm of chemical fertilizers and 500 gm of composts applied in 7 kg of soil is considered normal dose. Results are given in Table 5.

Table 5: Agronomic impacts of earthworms and vermicompost vis-a-vis chemical fertilizers and composted cow manure on growth and development of potted wheat crops (average growth in cm)

Parameters studied	Control (No input)	Treatment-1 chemical fertilizers (5 gm x 3 times)	Treatment-2 composted cow manure (500 gm)	Treatment-3 earthworms + vermicompost (500 gm)
Seed sowing	11 <sup>th</sup> Sep. 2008	Do	Do	Do
Seed germination	5 <sup>th</sup> Day	5 <sup>th</sup> Day	5 <sup>th</sup> Day	3 <sup>rd</sup> Day
Avg. growth in 2 wks	17	17	16	19
Avg. growth in 4 wks	20	29	30	31
Avg. growth in 5 wks	22	36	31	39
Avg. growth in 7 wks	24	37	32	41
Avg. growth in 8 wks	24	39	32	42
Avg. growth in 9 wks	26	39	32	43
Appearance of seed ears in wk 10	None	None	None	Yes
Avg. growth in 11 wks	26	39	32	43
Appearance of seed ears in wk 11	None	Yes	None	Yes
Avg. growth in 12 wks	26	43	32	47
Appearance & size of Seed ears (In wk 12)	Yes. Small & unhealthy	Small, but healthy	Yes. Small but healthy	Grew bigger in size and very healthy

Source: Chauhan (2009); Griffith University, Australia

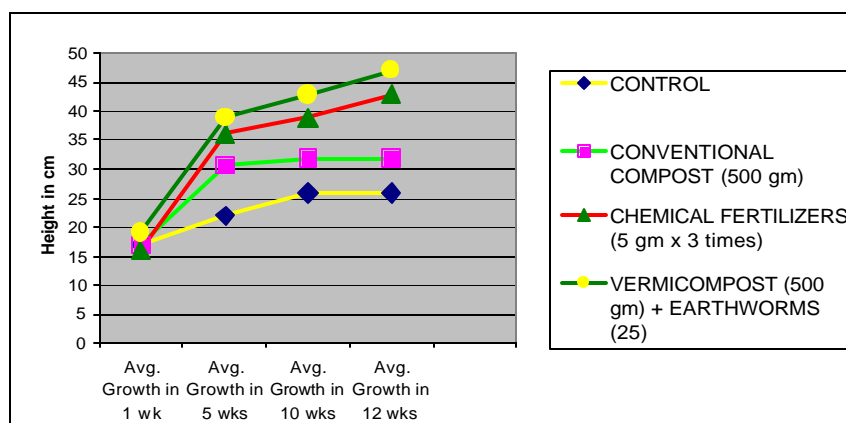
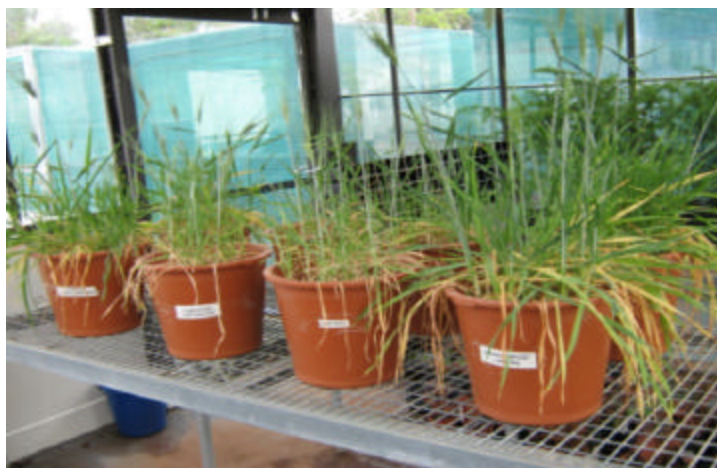


Fig. 5: Graph showing growth performances of wheat crops on vermicompost & earthworms, conventional compost (cow manure) & chemical fertilizers in 12 weeks period

**Important observations, findings and discussion:** Wheat crops maintained very good growth on vermicompost & earthworms from the very beginning & achieved maturity in just 12 weeks. The striking rates of seed germination were very high, nearly 48 hours (2 days) ahead of others and the numbers of seed germinated were also high by nearly 20%. Plants were greener and healthier over others, with large numbers of tillers & long seed ears were formed at maturity. Seeds were healthy and nearly 35-40% more as compared to plants on chemical fertilizers. The total growth performances of wheat crops (in terms of health, color and texture of shoots & leaves) on vermicompost & earthworms was significantly better over the chemical fertilizers. What they achieved in 89 weeks, was achieved by those on chemicals in 12 weeks. More significant was that the pot soil with vermicompost was very soft & porous and retained more moisture. Pot soil with chemicals were hard and demanded more water frequently.





A B C D

Photo showing final growth of wheat crops and development of seed ears after 12 weeks

Keys: (A). Chemical Fertilizer (NPK + Mg+ S+Fe+B+Zn 5 gm x 3 times) → 43 cm

(B). Composted cow manure (500 gm) → 32 cm

(C). Control (No input) → 26 cm

(D). Vermicompost (500 gm) + Earthworms (25 Nos.) → 47 cm



A B C D

Photo showing ripe and mature seed ears in wheat crops after 14 weeks

Keys: (A). Vermicompost + Earthworms

(B) Chemical Fertilizer

(C) Composted cow manure

(D) Control

**5) Agronomic Impact Studies of Vermicompost Vis-a-vis Conventional Compost & Chemical Fertilizers on Potted Corn Crops (Griffith University, Brisbane, Australia, 2008):** Valani (2003) studied it as a part of 40 CP honours project. It was designed to compare the growth promoting abilities of vermicompost & earthworms with conventional compost (composted cow manure) & chemical fertilizers on corn crops. Conventional compost & chemical fertilizers were bought from nursery while vermicompost was prepared by composting food & garden wastes. The pots were organised in the same way as described above and same inputs were applied in same amounts. Results are given in Table 6.

Table 6: Agronomic impacts of earthworms and vermicompost vis-a-vis chemical fertilizers and composted cow manure on growth and development of potted corn crops (average growth in cm)

Parameters studied	Control (No input)	Treatment-1 chemical fertilizers (5 gm x 3 times)	Treatment-2 composted cow manure (500 gm)	Treatment-3 Earthworms+ vermicompost (500 gm)
Seed sowing	22 <sup>nd</sup> sep. 2008	Do	Do	Do
Seed germination	3 <sup>rd</sup> day	3 <sup>rd</sup> day	4 <sup>th</sup> day	4 <sup>th</sup> day
Avg. growth in 2 wks	35	26	33	31
Avg. growth in 4 wks	45	45	35	60
Avg. growth in 5 wks	62	60	41	66
Avg. growth in 6 wks	70	90	69	120
Avg. growth in 7 wks	75	110	83	160
Avg. growth in 8 wks and app. of rep. organs	80 none	158 male rep. organ.	85 none	187 male rep. organ
Avg. growth in 9 wks and app. of rep. organs	No Growth male rep. organ	No growth	No growth male rep. organ	No growth female rep. organ
Avg. growth in 10 wks & Appearance of rep. organs	No growth	165 female rep. organ	No growth	195
App. of new corn (in wk 11)	None	None	None	New corn
Color & texture of leaves	Pale & thin leaves	Green & thin	Pale & thin leaves	Green, stout & broad leaves

Source: Valani (203); Griffith University, Australia

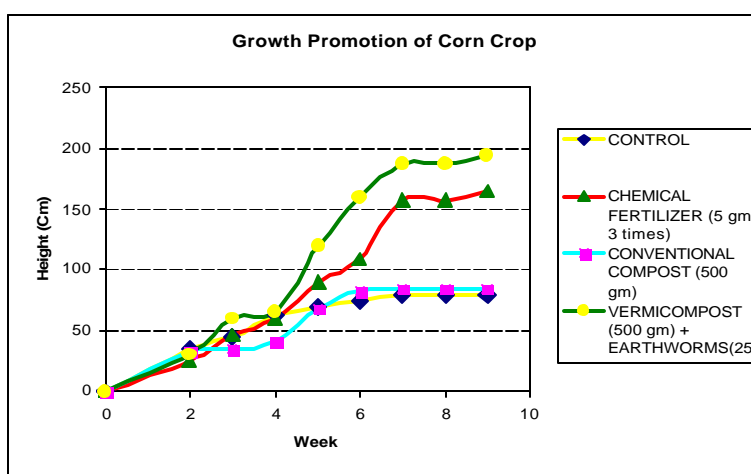


Fig. 6: Graph showing growth of corn crops promoted by vermicompost, conventional compost (composted cow manure) and the chemical fertilizers

**Important observations, findings and discussion:** Corn plants maintained very good growth on vermicompost & earthworms with male and female reproductive organs appearing in just 9 weeks. There were four (4) 'new corns' appearing on each plant in the two replicas. Corn plants on chemical fertilizers also grew well and had both reproductive organs appearing in 10<sup>th</sup> week. However, there were only two (2) 'new corns' appearing on each plant in the two replicas. The growth performances of corn plants on vermicompost & earthworms was nearly 15% better over the chemical fertilizers.



Photo showing final growth of corn crops after 10 weeks  
Keys: (A). Control (No input) → 80 cm  
(B). Composted cow manure (500 gm) → 85 cm  
(C). Chemical Fertilizer (NPK + Mg+ S+Fe+B+Zn 5 gm x 3 times) → 165 cm  
(D). Vermicompost (500 gm) + Earthworms (50) → 195 cm



Photo showing large 'new corn' appearing on corn plant grown on vermicompost & earthworms (After 11 Weeks)

A very significant observation was that the SOIL condition in the pots applied with vermicompost & worms was highly porous and SOFT while the one added with chemical fertilizers was non-porous and HARD.

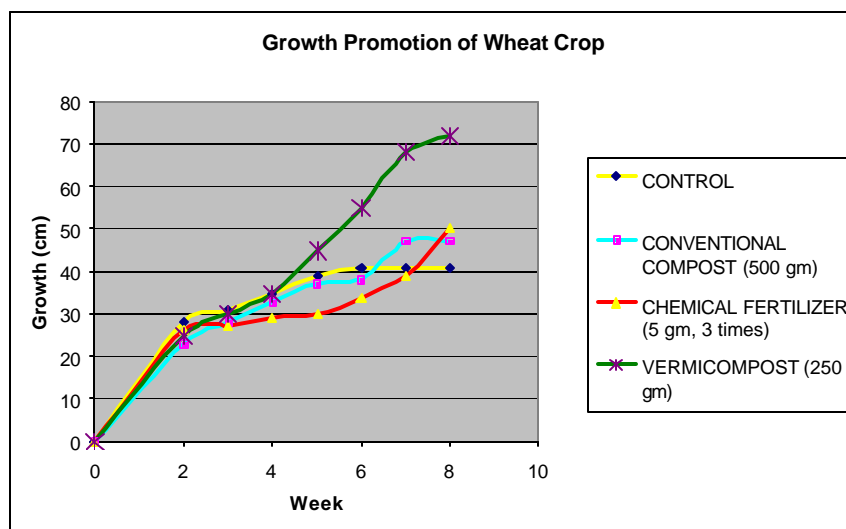
**AGRONOMIC IMPACT STUDIES OF VERMICOMPOST VIS -A-VIS CONVENTIONAL COMPOST & CHEMICAL FERTILIZERS ON POTTED WHEAT CROPS (GRIFFITH UNIVERSITY, BRISBANE, AUSTRALIA, 2008)**

Valani (203) also studied it as a part of 40 CP honours project. It was designed to compare the growth promoting abilities of 'lower doses of vermicompost' (250 gm-half of the amount used in earlier study on wheat crops) with full doses of conventional compost (500 gm) and normal dose of chemical fertilizers. This time vermicompost was prepared from 'food & garden wastes' mixed with 'cattle dung' and added with lime. The pots were organised in the same way as above. Results are given in Table 7.

Table 7: Agronomic impacts of 50% reduced doses of vermicompost vis-à-vis normal doses of conventional compost and chemical fertilizers on potted wheat crops (average growth in cm)

Parameters studied	Control (No input)	Treatment-2 composted cow manure (500 gm)	Treatment-3 soluble chemical fertilizers (5 gm x 3 times)	Treatment-4 vermicompost (250 gm) (no worms)
Seed sowing	17 <sup>th</sup> , March 2009	Do	Do	Do
Seed germination	4 <sup>th</sup> Day	4 <sup>th</sup> Day	5 <sup>th</sup> Day	3 <sup>rd</sup> Day
Avg. growth in 2 wks	28	23	26	25
Avg. growth in 3 wks	31	28	27	30
Avg. growth in 4 wks	35	33	29	35
Avg. growth in 5 wks	39	37	30	45
Avg. growth in 6 wks and Appearance of seed ears	41 None	38 None	34 None	55 Yes
Avg. growth in 7 wks and Appearance of seed ears	No growth Yes	47 Yes	39 Yes	68
Avg. growth in 8 wks	No growth	47	50	72
Size & health of seed ears (Wk 8)	Small and unhealthy	Small and unhealthy	Small, but healthy	Big in size and very healthy

Source: Valani (203); Griffith University, Australia



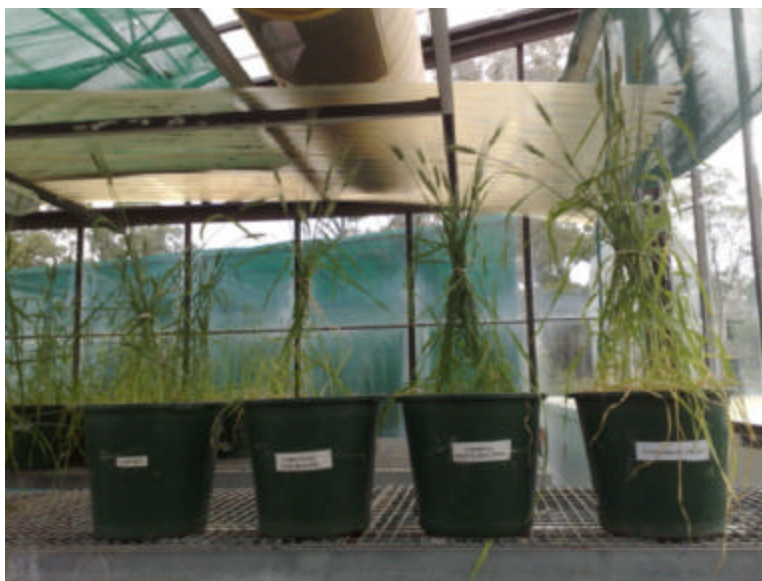


Photo showing final growth of wheat crops and development of seed ears after 10 weeks

Keys: A) Control → 41 cm

B) Composted Cow Manure (500 gm) → 47 cm

C) Chemical Fertilizer (NPK + Mg+ S+Fe+B+Zn; 5 gm x 3 times) → 50 cm

D) Vermicompost (250 gm) → 72 cm

**Important observations, findings and discussion:** Vermicompost applied wheat crops again excelled in growth over both conventional compost and the chemical fertilizers and also attained maturity faster. But more important finding was that this was achieved at 'HALF' the dose of vermicompost used in earlier studies for wheat crops (51). This clearly establishes that vermicompost prepared from 'cattle dung' as one of the raw materials and added with 'lime' contains more NPK and other growth promoting 'biochemical factors' and testifies the findings of Pramanik (138).

#### **AGRONOMIC IMPACT STUDIES OF VERMICOMPOST IN LOWER & HIGHER DOSES (100 GM-500 GM) ON POTTED WHEAT CROPS (GRIFFITH UNIVERSITY, BRISBANE, AUSTRALIA, 2009)**

Valani (203) also studied it as a part of 40 CP honours project. It was designed to compare the growth promoting abilities of vermicompost in lower to higher doses (100-500 gm) in pot soil to ascertain the 'optimum amount' of vermicompost that should be applied to wheat crops to achieve best growth and development. About 7 kg of near neutral soil devoid of any organic matter was used in pots. It had five (5) treatments with two (2) replicas of each and a control. Vermicompost was again prepared from food & garden wastes mixed with 'cattle dung' and added with lime. Results are given in Table 8.

**Important observations, findings and discussion:** Although the wheat crops grown in all pots from 100 gm to 500 gm of vermicompost showed good growth over the control, the one on 200 gm of vermicompost (C) exhibited overall best growth performance in terms of height & health (Avg. 72 cm) of individual plants, number of tillers (Avg. 2 in each plant), size of seed ears and seed grains which was distinctly larger & bigger over all others. Plants on 400 & 500 gm of vermicomposts (E & F) also gained good growth but the seed ears & grains were not as big & healthy as the one on 200 gm of vermicompost (C).

The inference drawn from the above study is that there is an 'optimum amount of vermicompost' in soil that can promote 'best growth' in wheat crops. Less than that becomes 'inadequate' in maintaining the appropriate

Table 8: Growth promoted by low and high doses of vermicompost on potted wheat crops (average growth in cm)

Parameters studied	Control (No input)	T-1 VC (100 gm)	T-2 VC (200 gm)	T-3 VC (300 gm)	T-4 VC (400 gm)	T-5 VC (500 gm)
Seed sowing	20 <sup>th</sup> , March 2009	Do	Do	Do	Do	Do
Seed germination	4 <sup>th</sup> Day	4 <sup>th</sup> Day	3 <sup>rd</sup> Day	4 <sup>th</sup> Day	3 <sup>rd</sup> Day	3 <sup>rd</sup> Day
Avg. growth in 2 wks	22	22	25	19	19	20
Avg. growth in 3 wks	32	33	32	35	38	37
Avg. growth in 4 wks	32	34	39	38	40	39
Avg. growth in 5 wks	35	35	40	39	41	40
Avg. growth in 6 wks and appearance of seed ears	40	43	50 Yes	45	45	47 Yes
Avg. growth in 7 wks and appearance of seed ears	50 Yes	55 Yes	68 Yes	61 Yes	70 Yes	66 Yes
Avg. growth in 8 wks; Size of seed ears & grain	55 Small & unhealthy	60 Small & unhealthy	72 Bigger & healthy	70 Small & unhealthy	73 Big & healthy	71 Big & healthy

Source: Valani (203); Griffith University, Australia; Keys: T = Treatment; VC = Vermicompost

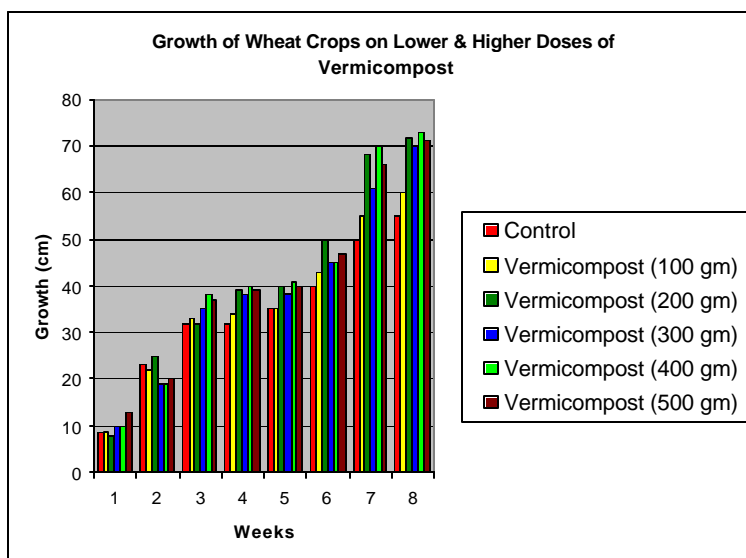


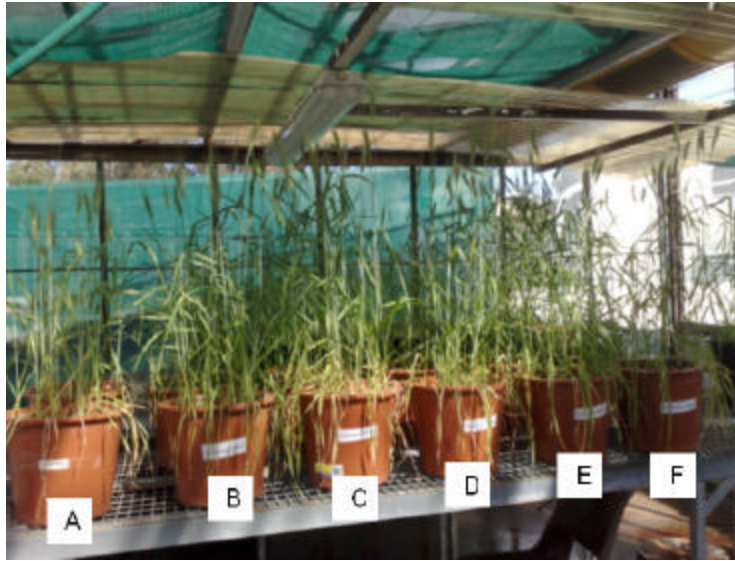
Fig. 8: Graph showing growth of wheat crops on lower & higher doses of vermicompost (100 gm-500 gm)

supply of nutrients and more than that may just remain in soil without contributing much to plant growth. More studies will be needed on these aspects. Again, the study established that vermicompost prepared from raw materials where ‘cattle dung’ is an important ingredient is superior and contain more nutrients for better growth promotion and thus, supporting the findings of Pramanik (138). This study also supports the findings of Subler (180) who found that the best growth responses were exhibited when the vermicompost constituted a relatively smaller proportion of the total volume of the container medium.

**(B). Studies on farmed wheat crops**

**1) Agronomic impact studies of earthworms and vermicompost vis-a-vis conventional cattle dung compost and chemical fertilizers on farmed wheat crops (University of Rajasthan, Jaipur, India, 2000-03):** Sharma (161) studied it for her Ph.D program. This facility was provided by Agriculture Research Institute at Jaipur. The





Final growth of wheat crops on lower & higher doses of vermicompost (100 mg-500 mg) after 8 weeks

Keys: A) Control → 55 cm

B) Vermicompost (100 gm) → 60 cm

C) Vermicompost (200 gm) → 72 cm (Overall Best)

D) Vermicompost (300 gm) → 70 cm

E) Vermicompost (400 gm) → 73 cm

F) Vermicompost (500 gm) → 71 cm

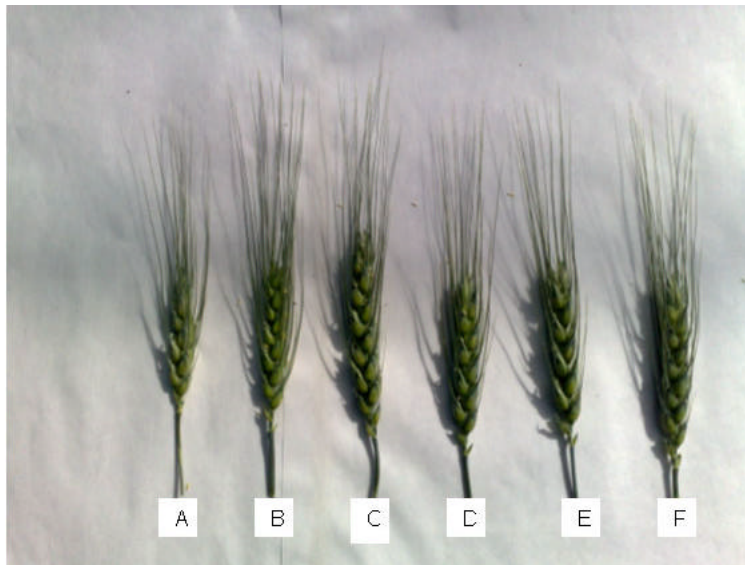


Photo showing size of seed ears & grains in wheat crops grown on increasing doses (100 gm-500 gm) of vermicompost

A) Control; B) Vermicompost (100 gm); C) Vermicompost (200 gm); D) Vermicompost (300 gm); E) Vermicompost (400 gm); F) Vermicompost (500 gm)

farm was divided into eight plots of 25 x 25 sq m size. Four treatments were prepared with one control. All the treatments were replicated twice. Vermicompost was applied @ 2.5 tonnes/ha in the 1<sup>st</sup> treatment plot. One thousand mature adult earthworms (mixed species of *E. fetida*, *P. excavatus* & *E. euginae*) were spread evenly throughout the 2<sup>nd</sup> treatment plot. Chemical fertilizers as urea for nitrogen (N), single super phosphate (P) and murete of potash (K) were applied in reduced doses (90:75:60) in the 3<sup>rd</sup> treatment plot along with full dose of vermicompost @ 2.5 tons/ha. In the 4<sup>th</sup> treatment plot full dose of NPK (120:100:80) was applied. Urea was applied in two split doses (first half at the time of sowing and second half dose after 21 days of sowing) whereas the phosphate and potash were applied as single dose at the time of sowing. They were used @ kg/hectare. Wheat seed was grown @ 100 kg/ha. Results are given in Table 9.

Table 9: Agronomic impacts of earthworms, vermicompost vis-a-vis chemical fertilizers on growth and yield of farmed wheat crops

Treatments	Shoot length (cm)	Ear length (cm)	Root length (cm)	Wt. of 1000 grains (In grams)	Grains /Ear
1 Vermicompost (@ 2.5 t/ha)	83.71	13.14	23.51	39.28	32.5
2 Earthworms (1000 Nos.)	67.83	9.85	18.42	36.42	30.0
3 NPK (90:75:60) (Reduced Dose) + VC (Full Dose) (2.5 t/ha)	88.05	13.82	29.71	48.02	34.4
4 NPK (120:100:80) (Full Dose)	84.42	14.31	24.12	40.42	31.2
5 Control	59.79	8.91	12.11	34.16	27.7

Source: Sharma (2001): Ph.D Thesis; University of Rajasthan, Jaipur, India

Keys: VC = Vermicompost; N = Urea; P = Phosphate; K = Potash (In Kg/ha)

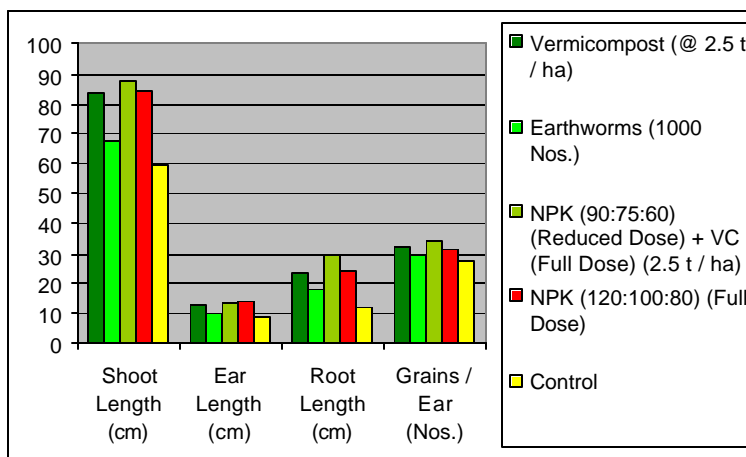


Fig. 9: Graph showing growth & yield of farmed wheat crops promoted by earthworms & vermicompost in exclusive application & chemical fertilizers in full & reduced doses

**Important observations, findings and discussion:** In the farm experiment the highest growth and yield in wheat crop was achieved where reduced dose (3/4) of chemical fertilizer (NPK-90:75:60) were supplemented with full dose of vermicompost @ 2.5 tons/ha. However, the total yield of the grain (grain/ear) as well as the ear length of crops grown on vermicompost were as good as those grown on full doses of chemical fertilizers (NPK-120:100:80). Although vermicompost alone can work as ‘driving force’ but when chemical fertilizers are added as ‘helping hand’ it can perform little better. Earthworms alone in soil, are not able to promote growth to any significant extent, but its metabolic products (vermicast) can. It infers therefore, that the worms cast (vermicompost) in soil works as the ‘storehouse’ of growth promoting factors e.g. the nutrients mineralised & the



plant growth hormones secreted by the worms. Worms would need sufficient feed materials (organic residues of crops) in farm soil to feed upon and excrete out their vermicast into the soil.

**2) Agronomic impact studies of vermicompost vis-a-vis conventional cattle dung compost and chemical fertilizers on farmed wheat crops**

**(Collaborative Research Program, Griffith University, Brisbane, Australia and Rajendra Agriculture University, Bihar, India) a) Study-1 (2007-2008):** This facility was provided by RAU, (Pusa campus). We studied the agronomic impacts of vermicompost and compared it with cattle dung compost & chemical fertilizers in exclusive application and also in combinations on farmed wheat crops. Cattle dung compost was applied four (4) times more than that of vermicompost as it has much less NPK values as compared to vermicompost. Vermicompost was prepared primarily from ‘cattle dung’ mixed with ‘food & farm wastes’. That is the usual practice in India. Results are given in Table 10

Table 10: Agronomic impacts of vermicompost, cattle dung compost vis-a-vis chemical fertilizers on growth & yield of farmed wheat crops

Treatment	Input/Hectare	Yield/Hectare
1) Control	(No Input)	15.2 Q/ha
2) Vermicompost (VC)	25 Quintal VC/ha	40.1 Q/ha
3) Cattle Dung Compost (CDC)	100 Quintal CDC/ha	33.2 Q/ha
4) Chemical Fertilizers (CF)	NPK (120:60:40) kg/ha	34.2 Q/ha
5) CF+VC	NPK (120:60:40) kg/ha+25 Q VC/ha	43.8 Q/ha
6) CF+CDC	NPK (120:60:40) kg/ha+100 Q CDC/ha	41.3 Q/ha

Source: Suhane et. al., (2008): Keys: N = Urea; P = Single Super Phosphate; K = Murete of Potash (In Kg/ha)

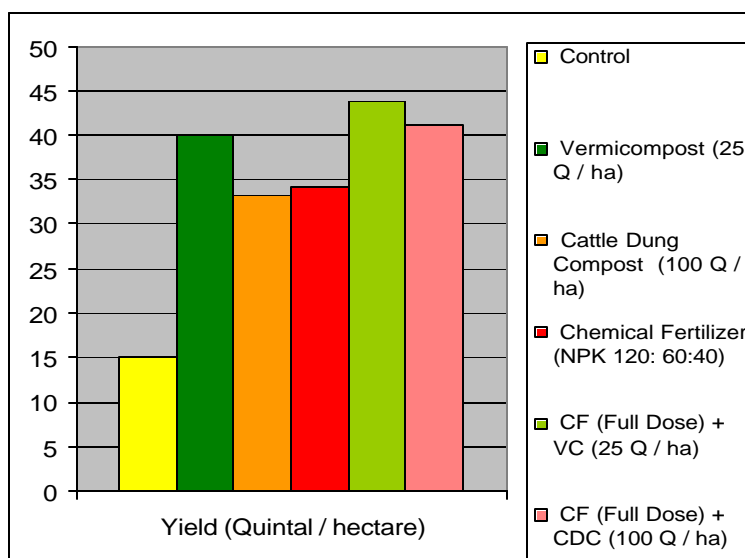


Fig. 10: Graph showing growth & yield of farmed wheat crops on vermicompost, cattle dung compost & chemical fertilizers in exclusive applications & on composts in combination with chemical fertilizers

**Observations, findings and discussion:** Exclusive application of vermicompost promoted yield of wheat crops in farms significantly higher (40.1 Q/ha) over the chemical fertilizers (34.2 Q/ha) applied in full dose. This was nearly 18% higher over chemical fertilizers. And when same amount of agrochemicals were supplemented with

vermicompost @ 25 quintal/ha the yield increased to about 44 Q/ha which is only about 10% higher over the wheat crops grown on exclusive application of vermicompost. This 10% increase in production do not make much economic sense as it will be neutralized by the high cost of agrochemicals and hence the high cost of crop production.

On cattle dung compost applied @ 100 Q/ha (4 times of vermicompost) the yield was just over 33 Q/ha which is about 18% less than that on vermicompost and that too after using 400% more conventional composts.

Application of vermicompost had other agronomic, economic & environmental benefits. It significantly 'reduced the demand of water for irrigation' by nearly 30-40%. Test results indicated 'better availability of essential micronutrients and useful microbes' in vermicompost applied soils. Most remarkable observation was significantly 'less incidences of pests and disease' attacks in vermicompost applied crops.

**Study-2 (2008-2009):** This facility was provided by College of Horticulture, RAU, (Noorsarai Campus). This time we studied the agronomic impacts of vermicompost on wheat crops on a lower dose applied @ 20 Q/ha against 25 Q/ha applied in Study-1 and compared it with chemical fertilizers applied in full dose as in Study-1. Four (4) types of farm plots were selected for vermicompost studies. In three of them (2<sup>nd</sup>, 3<sup>rd</sup>, & 4<sup>th</sup> plots) vermicomposts were applied in previous 1, 2 and 3 years successively by farmers for growing various cereal and vegetables crops. This was the 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> year of farming respectively by vermicompost in plots 2, 3 & 4. In plot 1, it was 1<sup>st</sup> year of farming by vermicompost. Previously chemical fertilizers were used for farming in this plot. Vermicompost was prepared from 'cattle dung' mixed with 'food & farm wastes'. Results are given in Table 11

Table 11: Agronomic impacts of vermicompost on growth and yield of farmed wheat crops upon successive applications over 1-4 years

Treatment	Input/Hectare	Yield/Hectare
1) Control	(No Input)	15.8 Q/ha
2) Vermicompost	20 Q/ha (1st Year Farming by VC)	35.3 Q/ha
3) Vermicompost	20 Q/ha (2 <sup>nd</sup> Year Farming by VC)	36.2 Q/ha
4) Vermicompost	20 Q/ha (3rd Year Farming by VC)	37.3 Q/ha
5) Vermicompost	20 Q/ha (4 <sup>th</sup> Year Farming by VC)	38.8 Q/ha
6) Chemical Fertilizers	NPK (120:60:40) kg/ha	35.4 Q/ha

Source: Singh *et al.*, (2009): Keys: VC = Vermicompost; N = Urea; P = Single Super Phosphate; K = Murete of Potash

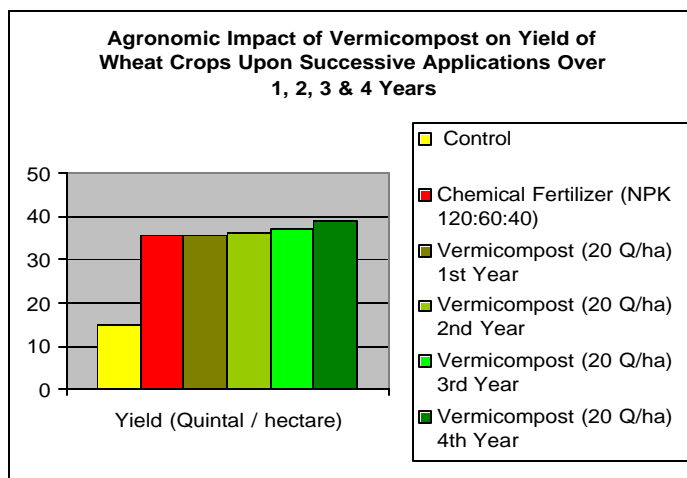


Fig. 11: Graph showing yield of farmed wheat crops on successively applied vermicompost in soil over 1-4 years

**Important observations, findings and discussion:** Vermicompost excelled chemical fertilizers in promoting crop growth in all types of plots studied. But what was most significant and exciting observation, was that in the farm plots 2, 3 & 4 where vermicompost was applied in the 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> successive years, the growth & yield of wheat crops increased gradually over the years even at the same amount of vermicompost applied i.e. @20 Q/ha. In the 4<sup>th</sup> successive year the yield was 38.8 Q/ha which was close to one where vermicompost was applied @ 25 Q/ha in Study-1 (40.1 Q/ha). However, the plot with 1<sup>st</sup> year of farming by lower dose (20 Q/ha) of vermicompost (after a changeover from chemical fertilizers) the yield was significantly lower (35.3 Q/ha) than those in Study-1 (40.1 Q/ha), but still close to those on chemical fertilizers (35.4 Q/ha). Crop yield on chemical fertilizer this time was little higher (35.4 Q/ha) as compared to Study-1, where it was 34.2 Q/ha on the same amount of chemicals used (NPK-120:60:40 kg/ha). This could be due to better farm soil in this region of the state. Increased yield in control plot (without any input) also indicate better soil conditions.

Above study conclusively prove that application of vermicompost 'build the soil quality' and 'improve its natural fertility' over successive years of application and over the years the total yield of crops should increase even at the same rate of application of vermicompost. It is also inferred from this study that over years of application, the amount of vermicompost could be reduced gradually while maintaining same levels of yield & productivity. However, more studies will be needed on these aspects.

### CONCLUSIONS AND REMARKS

Results of our studies on vermiculture made in Australia and in India, both in potted and farm crops, established beyond doubt that the 'earthworms vermicompost' works as an 'excellent organic fertilizer' and is nutritionally much superior and more powerful growth promoter (especially if prepared from 'cattle dung' as a raw material) than the conventional composts and can compete with chemical fertilizers as a 'nutritive', 'protective', 'cheaper' and 'sustainable' alternative to the 'destructive' chemical fertilizers for safe food production. Vermicompost provide more 'bio-available nutrients' to crops over time and also have some critical growth promoting 'biochemical factors' not found in conventional composts and cannot be made available by chemical fertilizers. Vermicompost applied crops may show slower growth in the beginning but as they slowly release nutrients & growth hormones and the baby worms grow from their cocoons and multiply in numbers, increase their metabolic activities & build up soil fertility, plants picks up rapid growth. Vermicompost applied soils are more 'soft' and 'porous' that facilitate better root growth and penetration. It also has better 'water holding' capacity. Use of vermicompost also induces crops to attain maturity faster and bear flowers, fruits and seeds.

The 18% increase (over chemical fertilizers) in yield of wheat crops grown on vermicompost in our farm studies made in India (2007-08) has great significance. This was in the beginning years while the farm soil was still recovering from the ill-effects of agro-chemicals used for several long years. In one of the study where chemical fertilizers were supplemented with vermicompost the yield exceeded. However, it do not make any big economic and ecological sense in using chemical fertilizers (even in reduced doses) with vermicompost for achieving small gain in crop yield. The cost of food production will go much higher as the cost of chemical fertilizers (produced from vanishing & costly geological resources) is much higher (and is rising throughout the world) as compared to vermicompost which is produced from 'organic wastes' including municipal solid wastes (MSW) of which there is no dearth and is easily available in plenty in every country needing safe disposal. The ill effects that the agrochemicals have on farm soils and water bodies also cannot be undermined.

Then there is an 'optimum value' of vermicompost per kg of soil in pots or per hectare of land in agriculture farms that can promote best growth in any crop. And this is relatively 'smaller' as compared conventional composts. Higher doses of vermicompost e.g. 300-500 gm did not necessarily exhibit higher growth performances in potted wheat crops as compared to those on 200 gm (203). In farm production, 20-25 quintal of vermicompost per hectare appears to be an 'optimal' amount for a good crop yield in the initial years but which should go down subsequently over 5-10 years as soil's physical, chemical and biological properties is improved and its natural fertility is restored. Our study shows that over successive years of application of vermicompost the yield of crops increases even at the same rate of application of vermicompost, also inferring that the amount of vermicompost could be gradually reduced after some years while maintaining same yield. Webster (206) found

that vermicompost increased yield of 'cherries' for three (3) years after 'single application' inferring that use of vermicompost in soil builds up fertility and restore its vitality for long time and its further use can be reduced to a minimum after some years of application in farms. Such growth performances of crops in response to smaller doses of vermicompost was also indicated by Subler (180) and Valani, (203). In all growth trials the best growth responses were exhibited when the vermicompost constituted a relatively small proportion (10%-20%) of the total volume of the container medium. Surprisingly, greater proportions of vermicomposts in the plant growth medium not always improved plant growth (180) but also never had any adverse impact on the plants. Our studies on potted wheat crops where 200 gm of vermicompost performed better over 500 gm of vermicompost also supports this contention (203). These findings are contrary to the growth responses of chemical fertilizers whose rate of application per hectare have gradually increased over the years since the green revolution of 1960s to maintain the same yield of previous years and higher doses of chemical fertilizers always made 'adverse impact' on crops rather than benefiting them.

Our studies also testified the findings of Pramanik (138) who reported that vermicompost prepared from 'cattle dung' applied with 'lime' is nutritionally more superior. In cattle dung vermicompost nitrogen (N) was higher by 275%, humic acid by 0.7963 mg/g. In MSW vermicompost nitrogen (N) was higher by 178% & humic acid 0.3917 mg/g. Phosphorus (P) & Potassium (K) were also significantly higher in cattle dung vermicompost as compared to MSW vermicompost. Chauhan (51) studied the agronomic impacts of vermicompost prepared from MSW (food & garden wastes) on wheat crops. The plants achieved smaller growth (47 cm) and matured in 12 weeks on 500 gm of vermicompost. Valani (203) studied the agronomic impacts of vermicompost (prepared from MSW mixed with 'cattle dung' and added with 'lime') on wheat crops and found that the plants achieved better growth (55 cm) and also maturity, in just 6 weeks. More significant was that it was on 250 gm of vermicompost (half the dose used by Chauhan (51)).

Another interesting observation in our studies has been the varied growth impacts of vermicompost when applied with & without worms. From the studies of Sharma (161) and Sinha & Bharambe (175) it became apparent that worms alone cannot promote significant growth. But that together they can reinforce good growth is established from all other studies. But again, other studies (161; 183 & 203) indicated that exclusive application of vermicompost in wheat crops can support very good growth and much better over chemical fertilizers. Vermicompost applied soils, however, eventually harbour large population of worms as it contains plenty of worms 'cocoon' that soon germinate in soil to produce baby worms. It is also a scientific fact that although the worms secrete the 'growth promoting biochemical factors' (plant enzymes, hormones and humic acids) and mineralise 'plant nutrients', it is eventually stored in its metabolic products (vermicast).

It is also a possibility, for which more studies will be needed, that earthworms and its vermicast respond differently to different crops. Agarwal (4) studied their growth impacts on vegetable crops (okra & egg-plants) where worms played very important role. Sharma (161), Sinha & Bharambe (175), Suhane (183), Valani (203) & Singh (167) studied it on cereal crops (wheat & corn) where presence or absence of earthworms in soil was not so important, but its 'metabolic product' was certainly important.

Earthworms and its vermicompost can work as the main 'driving force' in sustainable food production for food security while maintaining soil health and fertility. They can 'completely eliminate' the use of chemical fertilizers and 'significantly reduce' the use of chemical pesticides in crop production & also the huge water requirements for crop irrigation which became essential in chemical agriculture. This is being termed as 'Sustainable Agriculture' (2; 140 & 172).

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#### **Useful websites on vermiculture studies**

- <http://www.alternativeorganic.com> (Good Earth People, Canada).  
<http://www.kvksmp.org> (Farmers Training on Vermicomposting at RAU, Bihar, India).  
<http://www.rirdc.gov.au> (Australian Govt. Pub. On EARTHWORMS).  
<http://www.vermitech.com> (Australian Company in Vermiculture Business).  
<http://www.vermitechology.com> (U.S. Company in Vermiculture Business).  
(<http://www.wormwoman.com> (Mary Appelhof: Author of Classic Book 'Worms Eat My Garbage-Sold over 3500 copies).  
<http://www.wormdigest.org> ('Worm Digest'-A Quarterly Magazine).  
<http://www.wormresearchcentre.co.uk> (Earthworm Research Center in UK).

#### **Relevant Books by Dr. Rajiv K. Sinha**

1. Sinha, Rajiv K and Rohit Sinha, 2008. *Environmental Biotechnology (Role of Plants, Animals and Microbes in Environmental Management)* (pages 315), Aavishkar Publishers, India; ISBN 978-81-7910-229-9.
2. Sinha, Rajiv K., 2007. *Sustainable Development (Striking a Balance between Economy & Ecology)*, (pages 340), Pointer Publisher, India; ISBN 978-81-7132-499-6.
3. Sinha, Rajiv K., 2003. *Sustainable Agriculture: Embarking on the Second Green Revolution*, (pages 350), Surabhee Publisher, India; ISBN 81-86599-60-6.