

Scientific cultivation of water chestnut crop

a boon for poor fishermen

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Water chestnut (Trapa bispinosa), an annual aquatic angiosperm plant, found in tropical and sub-tropical regions, is commonly known as Singhara in Hindi. Further, water chestnut has a vast potential pertaining to its nutritional qualities for human beings. Moreover, its leaves all their biomasses in the same field where it grows. Henceforth, it contributes a lot of plant essential nutrients to the soil mass. Keeping in view of its importance a scientific work has been initiated at this Centre to develop a high-yielding variety. Previously, it was mainly grown in naturally formed ditches, shallow land or ponds in high rainfall areas. Thus the poor fishermen could not harvest its full potential at a larger extent. Now it was shown to the farmer that in the chaur (land depression between two streams) or low lands/ditches/ponds the crop can be taken in cropping system mode with fishes and foxnut (makhana) crop. And in this way they can double their income from the same piece of land.

Key words: Cultivation, Fishermen, Foxnut, *Trapa bispinosa*

INTEGRATED Farming System Model by integration of fish, water chestnut and foxnut was developed in 50 ha of land in Darbhanga district. The net benefit from the system was recorded at ₹ 68,545 (earning ₹ 1,26,505 with investment ₹ 57,960) compared with traditional system i.e. when foxnut production was done alone. Field-based system of *makhana* cultivation was standardized with other crops like fish, rice and water chestnut in cropping system model. The gross return from foxnut–fish, foxnut–rice and foxnut–water chestnut was obtained as ₹ 2,82,810, ₹ 2,73,840 and ₹ 3,54,340 per ha, respectively while a gross return of ₹ 1,32,552 was obtained from foxnut cultivation alone.

Water chestnut is mainly grown in Madhya Pradesh, Uttar Pradesh, Bihar and Odisha. It is distributed in temperate and tropical Asia and central and south-east Europe. In India it is extensively grown in Bihar, Madhya Pradesh, Uttar Pradesh, West Bengal, Odisha, Jharkhand, Karnataka, and Jammu and Kashmir. On the basis of morphology of fruit of water chestnut, it is of two types:

one is thorny and another one is thornless. In Bihar, only red thorny fruit type water chestnut is found. However, in Madhya Pradesh and Uttar Pradesh, both the thornless and thorn bearing fruit plants are found. For the varietal development programme the germplasms of water chestnut have been collected from Darbhanga (02) districts of north Bihar, and Madhya Pradesh. Out of 13 collected thornless germplasms from Madhya Pradesh, 08 were red and 05 green. Some thornless germplasm was also selected from Odisha, Jharkhand and Uttar Pradesh.

The species is characterized by free floating plants with submerged and floating leaves. Its floating leaves are arranged in a rosette. Individually, the 2 to 4 cm long upper leaves are slightly rhombic to rhombic-ovate and are sharply dentate along the leaf margins. There are conspicuous veins on the lower surface as well as short, stiff hairs. The submerged lower leaves are alternate and feather-like and can reach up to 15 cm long. The petioles of the floating leaves are 0.6 to 1.8 m long. The inconspicuous

white flowers consist of four 8 mm long, white petals and four green sepals, and are located in the centre of the rosette. In water chestnut flowering begins in August.

The plant is commercially cultivated for its nutritious nuts. The fruit is a four-horned nut like structure about 3 cm wide that develops under water. Fruits ripen in a month and can remain viable up to twelve years. The dried fruit contains about 70% carbohydrate, 13% protein, 2 to 7% sugar, 0.8% fat, 3% mineral elements and plenty of iodine including significant amounts of vitamins including thiamine, riboflavin, nicotinic acid, vitamin C, vitamin A and phosphorylases, whereas the raw fruit contains 70% water, 23.3% starch (carbohydrate), 4.7% protein, 0.3% fat, 0.6% fibre and 1.1% minerals. The fruit can be consumed raw, boiled, roasted or dried to make flour. When the fruit has been dried, it is ground to flour called *singhare ka atta* which is used in many religious rituals and can be consumed as a *phalahar* diet on the Hindu fasting days, in Indian traditional festival 'Navratri'.



Fig 1. White-coloured Water chestnut flower

Trapa bispinosa is an important plant of Indian Ayurvedic system of medicine which is used in the problems of stomach, genito-urinary system, liver, kidney, and spleen. It is bitter, astringent, stomachic, diuretic, febrifuge, and antiseptic. The whole plant is used in gonorrhoea, menorrhagia, and other genital affections. It is useful in diarrhoea, dysentery, ophthalmopathy, ulcers, and wounds. Water chestnut is also beneficial for women. Due to its nutritive, strengthening and cooling properties it increases fertility and chances of conception. It is rich in proteins, carbohydrates, vitamin B, vitamin C, iron, calcium, magnesium, phosphorus, and iodine and helps to stabilize pregnancy and prevent abortion. These are used in the validated conditions in pitta, burning sensation, dipsia, dyspepsia, haemorrhage, haemoptysis, diarrhoea, dysentery, strangely, intermittent fever, leprosy, fatigue, inflammation, urethrorrhoea, fractures, erysipelas, lumbago, pharyngitis, bronchitis and general debility, and suppressing stomach and heart burning.

Evaluation of different genotypes of water chestnut (*Trapa bispinosa*)

Numbers of days required for first flowering were between 56 and 62 in JR1 (Jabalpur Red 1) to JR8, 60 to 65 in JG1 (Jabalpur Green 1) to JG5 and 60 days in DR1 (Darbhanga Red 1) and DR2 (Darbhanga Red 2), respectively, Table 1. Again fruit set started within 63 to 70 days in JR after planting and it was 69 to 73 in JG. Similarly maturity of fruit started between 95 and 104 days after planting in JR, JG and DR. There was marked variation in root length per plant. It was maximum in JR2

Table 1. Growth parameters of water chestnut plants

Geno- type	Flowering	Fruit set	Fruit maturity	No. of leaves per plant	Leaf size LXB (cm ²)	Root length (cm ²)	Length of fruiting branch (cm ²)
JR1	58	66	97	99	6 x 8	185	55.32
JR2	56	63	95	104	7 x 8	255	65.00
JR3	60	68	97	89	6 x 9	160	62.00
JR4	57	66	98	101	6 x 8	190	57.65
JR5	60	67	100	102	5 x 7	109	50.35
JR6	59	67	96	103	5 x 8	140	54.65
JR7	60	67	98	102	6 x 9	180	60.40
JR8	62	70	98	105	6 x 8	165	58.20
JG1	60	69	101	101	6 x 9	211	47.25
JG2	62	71	102	101	6 x 9	202	46.00
JG3	64	71	104	102	5 x 7	195	45.00
JG4	63	72	100	100	5 x 8	233	48.55
JG5	65	73	104	99	6 x 9	165	10.35
DR1	60	68	102	105	5 x 7	194	52.60
DR2	60	67	100	111	6 x 7	210	60.45

(255 cm) followed by JR1 (Table 1). Among the JG germplasm, JG4 recorded the maximum root length (233 cm). Similarly the highest length of fruit bearing branches was found in JR2 (65 cm) and JG4 (48.55 cm), Table 1. No marked differences were observed in leaf size of all the collected germplasm.

All the local collection namely DR group had three spines on the body of the fruit.

The colour of mature fruit was red in JR, green in JG and red in DR. The size of whole fruit as length and breadth varied from 5.1 cm × 12.6 cm to 7.3 cm × 14.3 cm in JR. The maximum fruit size was noticed in JR2. Among the JG germplasm, JG4 again recorded the highest fruit size

(6.3 cm × 13.5 cm), Table 2. But kernel size maximum varied from 4.57 cm × 11.45 cm to 7.01 cm × 13.65 cm and 4.4 cm × 11.74 cm to 5.35 cm × 12.78 cm in JR and JG4, respectively (Table 2). The variation in weight of kernel was at par in all the collections. Weight of individual fruit as well as kernel was also found to vary in different collections. Fruit weight ranged from 25 g in JR2 to 24.1 g in JR5 (Table 2). Accordingly in JG collections it varied from 20.9 g in JG 4 to 20.4 g in JG1. The variation between fruit weight and kernel was obviously due to content of skin of fruit which has not been worked out separately. Marked variations in number of fruits plant were recorded among the collected

Table 2. Yield parameters of water chestnut plants

Geno- types	Colour of fruit	Fruit size L x B (cm ²)	Kernel size L X B (cm ²)	Weight/ fruit (g)	Weight / kernel (g)	Kernel (%)	No. of fruits/ plant
JR1	Red	6.1 x 13.6	5.61 x 13.2	24.3	12.72	47.65	230
JR2	Red	7.3 x 14.3	7.01 x 13.65	25.0	13.69	45.24	250
JR3	Red	6.5 x 13.4	5.75 x 12.61	24.5	13.42	45.22	235
JR4	Red	5.1 x 12.6	4.57 x 11.45	24.6	12.48	49.26	240
JR5	Red	5.2 x 12.2	4.78 x 11.40	24.1	13.26	44.97	243
JR6	Red	6.0 x 13.5	5.24 x 12.87	24.5	11.42	53.38	246
JR7	Red	7.0 x 14.0	6.08 x 13.36	24.8	12.44	49.83	240
JR8	Red	7.1 x 14.1	6.53 x 13.46	24.6	13.50	45.12	245
JG1	Green	5.0 x 12.3	4.4 x 11.74	20.4	12.46	38.92	210
JG2	Green	5.1 x 11.6	4.71 x 10.26	20.8	12.77	38.60	195
JG3	Green	5.4 x 13.2	4.91 x 12.62	20.5	11.56	43.60	190
JG4	Green	6.3 x 13.5	5.35 x 12.78	20.9	12.45	40.43	218
JG5	Green	6.0 x 13.0	5.08 x 11.50	20.5	12.66	38.24	201
DR1	Red	5.2 x 9.3	4.66 x 8.61	22.0	11.56	47.45	220
DR2	Red	5.7 x 11.5	4.93 x 10.68	22.5	11.57	48.57	233

Table 3. Yield and nutritional properties of water chestnut plants

Genotypes	No. of fruiting branches	Wt. of 10 raw fruit (g)	Shelf-life (days)	Storage life at 10p c	Total soluble solid (p b)	Juice (%)	Yield per plant (kg)
JR1	5	243	4.0	8.0	9.0	51.0	5.58
JR2	7	250	4.0	8.0	9.2	53.3	6.25
JR3	4	245	4.0	8.0	8.4	52.0	5.75
JR4	3	246	4.0	8.0	8.4	52.3	5.90
JR5	5	241	4.0	8.0	8.2	52.1	5.85
JR6	5	245	4.0	8.0	8.4	52.3	6.02
JR7	4	248	4.0	8.0	9.1	52.5	5.95
JR8	5	246	4.0	8.0	8.6	52.2	6.02
JG1	5	204	4.0	8.0	7.3	56.20	4.28
JG2	5	208	4.0	8.0	7.5	56.52	4.05
JG3	6	205	3.5	8.0	7.2	56.41	3.89
JG4	6	209	4.0	8.0	7.5	57.00	4.55
JG5	6	205	4.0	8.0	7.2	55.41	4.12
DR1	5	220	3.0	6.0	6.4	52.50	4.84
DR2	5	225	3.0	6.0	6.6	52.70	5.25

germplasm. The maximum number of fruits/plant was found in JR2 (250) followed by DR2 (233) and JG4 (218), Table 2. Thus, it could be concluded that JR germplasm is having the highest yield potential when compared with JG and DR collections.

All the collection had same shelf-life and storage life at 10p c. Both parameters were slightly lesser in local collections. Number of fruiting branches was found to be maximum in JR2 (7) followed by JG4 (6) and DR2 (5), Table 3. Thus the marked variation in yield per plant was noticed among the collections. It was only 3.89 kg in JG3 and 6.25 kg in JR2. DR1 and DR2 produced an average yield of 4.84 and 5.25 kg, respectively. Pertaining to fat, fiber, water and mineral contents of fruit, no marked variation was observed among all the collections. However, the values of different quality parameters showed that the JR2 was the superior one among all the collected germplasm as the maximum protein (5.2%), carbohydrate (25%) and minimum acidity (0.242%) was recorded in JR2 only. The morphological and nutritional properties of water chestnut are given in Table 4.

Economic importance

The fruit of water chestnut is a nut of nutritional and medicinal value. It is sold both fresh and boiled in street

markets in India. With the introduction of thornless selection of water chest germplasm, the fishermen on an average are easily earning an additional income (by selling raw fruit only) of ₹ 2, 30,000/- from cultivation of the crop in 1 ha area. It has been recorded from Madhya Pradesh where it is grown in around 5,000 ha of land which fetches ₹ 20 to 25 crore/year. The immature pulp of the fruit, called milky water chestnut, is eaten raw or cooked, while the mature pulp is used to prepare dishes after boiling and drying. Fresh and boiled water chestnuts are used not only as vegetables, but also in tea and in preparing curries. The kernels are

dried and sold as nuts, and are also ground into flour for bread (*chapattis* or *poories*). The nutritive value of the fruits is similar to that of wheat. Water chestnut is also used for preparing tea in Japan, in the commercial production of wine, and for special food during festivals. A paste prepared by diluting the dough of water chestnut is an excellent diet for some patients.

Medicinal value

The medicinal values of the whole herb and fruit have been recognized in folklore medicine as a cure for various diseases. The whole herb has been reported for hepato-protective activity, antimicrobial activity, antibacterial activity, antitumor activity, antioxidant activity and free radical scavenging activity. The fruits were used as anti-inflammatory, anti-diarrhoea, intestinal astringent, antileprotic agent and in urinary discharges, fractures, bronchitis and anaemia. The fruits of *T. bispinosa* has been identified as the Ayurvedic drug *Shurangataka* as it has cancer-preventing properties. Stem juice is used in ophthalmic preparations.

Integration of fishes and water chestnut with fox nut

Pond of 1.0 acre (0.404 ha) size is selected and cleaned, and followed by removal of carnivorous fishes by applying *mahua* oil-cake @ 2.5 tonne/ha. Transplanting and gap filling work of fox nut plants was also

Table 4. Nutritional qualities of water chestnut plants

Genotype	Acidity (%)	Total sugar (%)	Protein (%)	Fat (%)	Fiber (%)	Water (%)	Carbo-hydrate (%)	Mineral (%)
JR1	0.244	4.63	4.3	0.3	0.4	71	23	1.0
JR2	0.242	4.70	5.1	0.2	0.5	69	25	1.2
JR3	0.244	4.64	4.4	0.2	0.4	70	24	1.0
JR4	0.243	4.65	4.0	0.3	0.5	71	23	1.2
JR5	0.246	4.62	4.2	0.3	0.3	72	22	1.2
JR6	0.248	4.64	3.6	0.2	0.2	72	23	1.0
JR7	0.246	4.67	4.3	0.2	0.5	71	23	1.0
JR8	0.243	4.65	4.5	0.2	0.3	70	24	1.0
JG1	0.265	3.94	4.2	0.3	0.5	72	22	1.0
JG2	0.265	3.96	4.3	0.2	0.5	70	24	1.2
JG3	0.262	3.95	4.2	0.2	0.6	73	21	1.0
JG4	0.260	3.98	5.5	0.1	0.4	70	23	1.0
JG5	0.263	3.94	4.3	0.2	0.5	70	25	1.0
DR1	0.292	3.78	3.0	0.2	0.6	72	23	1.0
DR2	0.290	3.82	3.1	0.3	0.6	72	25	1.0



Fig. 2. The foxnut+fish system in pond



Fig. 3. The water chest nut crop in foxnut pond

conducted for optimization of crop geometry @ 7,000 plants/ha. Likewise the foxnut plants, water chestnut are transplanted @ 10,000 plants/ha. The 10% area in the middle of pond was kept vacant as refuge area for proper oxygenation and better growth of fishes. The fish species (rohu, katla, common carp and mrigal) were integrated @ 6,000 numbers/ha as fingerlings in the ratio of 40:20:20:20, respectively between March and April, and again in September after harvest of Foxnut. The harvesting of fishes gets completed between December and January before the emergence of Foxnut crop. Water chestnut is harvested from October to November. Since it is sown in second week of August and gets ready for

first harvesting in the last week of October. The area under pond and agricultural land is discussed in the Tables 5 and 6, respectively.

To improve the livelihood of Foxnut growers the ICAR- NAIP project 'Sustainable livelihood improvement through need-based integrated farming system models in disadvantaged districts of Bihar' was initiated in April 2009 in 50 ha ponds of foxnut growers of Sadar block of Darbhanga district. During 2013-2014, the coverage area of this project was extended from one district to three districts (Darbhanga, Madhubani and Muzaffarpur) and the mode of water chestnut and foxnut cultivation widened from traditional ponds to shallow agricultural fields. Out of this 50 ha

area, 36.4 ha was allotted under traditional pond system while rest 13.6 ha was covered under field mode of foxnut cultivation.

Five years results of this multi-enterprize agricultural system are discussed here. In both systems, integrated concept of farming systems were adopted to augment the per unit area net income of foxnut growers. The results of this project are explained in Tables 5 and 6. These results indicated that the net returns in both integrated farming systems are near about two-fold of the solo foxnut production system. Among all combinations of two systems, foxnut–water chestnut (in field condition) was recorded to give the highest net return (₹ 1,56,436/-) to foxnut growers followed by

Table 5. Economic analysis of different combinations in pond system of Foxnut cultivation

Component combinations	Total area (ha)	Total production (tonne)			Average productivity (tonne/ha)			Gross return (₹)/ha	Net return (₹)/ha	Ranking of Net returns
		Foxnut seed	Fish	Water chest nut	Foxnut seed	Fish	Water chest nut			
Foxnut+Fish	22.60	33.67	14.01	—	1.48	6.75	—	2,05,270	1,02,635	III
Fox nut-Water chestnut	6.40	10.36	—	88.32	1.62	—	14.56	2,15,320	1,07,660	II
Foxnut+Fish-water chestnut	4.65	6.73	1.70	64.17	14.48	3.67	13.80	2,53,010	1,26,505	I
Foxnut	2.75	4.55	—	—	16.56	—	—	1,15,920	57,960	IV

Table 6 Economic analysis of different combinations in field mode of Foxnut cultivation

Component combinations	Total area	Total production (tonne)				Average productivity (tonne/ha)				Gross return (₹ /ha)	Net return (₹ /ha)	Ranking
		Foxnut	Fish	Water chestnut	Rice	Foxnut	Fish	Water chestnut	Rice			
Foxnut + Fish	8.40	24.02	3.78	-	-	2.84	0.56	-	-	2,82,810	1,21,520	II
Foxnut - Rice	3.00	9.07	-	-	12.36	3.02	-	-	41.20	2,73,480	1,16,322	III
Foxnut - Water chestnut	1.20	3.55	-	25.2	-	2.96	-	21.00	-	3,54,340	1,56,436	I
Foxnut	1.00	3.15	-	-	-	3.15	-	-	-	2,20,920	88,368	IV

foxnut+fish-water chestnut in ponds (₹ 1,26,505) Table 5, and Foxnut + Fish (₹ 1,21,520) Table 6, in field system. On the other hand, Fox-nut+Fish combination gave net return of ₹ 1,02,635 (Table 5) only which was at par with the net returns i.e., ₹ 1,07,660 only (Table 5) obtained from Foxnut-water chestnut combinations. The findings of this project suggested that integrated farming may be very helpful to improve the economic status of fox nut growers by providing sustainable livelihood to them.

SUMMARY

With the research of varietal development programme of water chestnut, it was observed that the fishermen have started growing water chestnut crop scientifically in their ponds or unused *chaur* lands in association with foxnut and fishes. Fishermen are happy with the newly identified thornless germplasm of water chestnut, as it is easy in plucking the fruit from the plants, transportation and post-harvest processing. As a result of this, the

fishermen are getting almost two-fold higher income in comparison to their previous activities. The highest benefit: cost ratio was recorded with Foxnut-water chestnut combination (1.79) followed by foxnut-fish combination in field system under integrated farming system model.

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Polluting our soils is polluting our future

Stop Soil Pollution: 6 reasons why soil pollution should not go unnoticed

Soil is a finite resource, meaning its loss and degradation is not recoverable within a human lifespan. Soils affect the food we eat, the water we drink, the air we breathe, our health and the health of all organisms on the planet. Without healthy soils we wouldn't be able to grow our food. In fact, it is estimated that 95 percent of our food is directly or indirectly produced on our soils.

Healthy soils are the key to food security and our sustainable future. They help sustain food production, mitigate and adapt to climate change, filter water, improve resilience to floods and droughts and so much more. Yet, an invisible threat is putting soils and all that they offer at risk.

Soil pollution causes a chain reaction. It alters soils' biodiversity, reduces soil organic matter and soils' capacity to act as a filter. It also contaminates the water stored in the soil and groundwater, and causes an imbalance of soil nutrients. Among the most common soil pollutants are heavy metals, persistent organic pollutants and emerging pollutants – like pharmaceutical and personal care products.

Soil pollution is devastating to the environment and has consequences for all forms of life that encounter it. Unsustainable agricultural practices that reduce soil organic matter can facilitate the transfer of pollutants into the food chain. For example: polluted soil can release contaminants into the groundwater, which goes on to accumulate in plant tissue, and is then passed to grazing animals, birds, and finally to the humans that eat the plants and animals. Pollutants in soil, groundwater and in the food chain can cause a variety of diseases and excess mortality in humans, from short-term acute effects, such as intoxications or diarrhea to long-term chronic effects, like cancer.

Beyond the impact on the environment, soil pollution also has high economic costs due to the reduction of crop yields and quality. The prevention of soil pollution should be a top priority worldwide. The fact that the vast majority of pollutants are a result of human action means that we are directly responsible for making the necessary changes to

ensure a less polluted, more secure future.

Soils need to be recognized and valued for their productive capacities as well as their contribution to food security and the maintenance of key ecosystem services. Here are just a few reasons why soil pollution can't be underestimated:

1. Soil pollution affects everything. The food we eat, the water we drink, the air we breathe – our health and the health of all the organisms on the planet is dependent on healthy soil. The nutrient content of a plant's tissues is directly related to the nutrient content of the soil and its ability to exchange nutrients and water with the plant's roots.

2. Soil pollution is invisible. Today, one third of our soils are moderately or highly degraded due to erosion, loss of soil organic carbon, salinization, compaction, acidification and chemical pollution. It takes about 1 000 years to form 1 cm of top soil, meaning that we won't be able to produce more soil within our lifetime. What we see is all there is. Yet, soils are facing even more pressure from soil pollution. The current rate of soil degradation threatens the capacity of future generations to meet their most basic needs.

3. Soil pollution affects soils' capacity to filter. Soils act as a filter and buffer for contaminants. The potential of soil to cope with the strain of pollutants is finite. If soil's capacity to protect us is exceeded, contaminants will (and do) seep into other parts of the environment – like our food chain.

4. Soil pollution affects food security by reducing crop yields and quality. Safe, nutritious and good quality food can only be produced if our soils are healthy. Without healthy soils, we won't be able to produce enough food to achieve #ZeroHunger.

5. Soil pollution can be a result of poor agricultural practices. Unsustainable agricultural practices reduce soil organic matter, compromising soils' capacity to degrade organic pollutants. This increases the risk of the pollutants being released into the environment. In many countries, intensive crop production has depleted the soil, jeopardizing

our ability to maintain production in these areas in the future. Sustainable agricultural production practices have therefore become imperative for reversing the trend of soil degradation and ensuring current and future global food security.

6. Soil pollution can put our health at risk. A significant proportion of antibiotics, used widely in agriculture and human healthcare, are released into the environment after being excreted from the organism to which they were administered. These antibiotics can seep into our soils and spread throughout the environment. This creates antimicrobial resistant bacteria, which decreases the effectiveness of antibiotics. Each year around 700 000 deaths are attributable to antimicrobial resistant bacteria. By 2050, if not tackled, it will kill more people than cancer, and cost, globally, more than the size of the current global economy.

With a global population that is projected to exceed 9 billion by 2050, our current and future food security hinges on our ability to increase yields and food quality using the soils that we already have available today. Soil pollution negatively impacts us all, and has been identified as one of the main threats to soil functions worldwide.

We need to be aware of the causes of soil pollution so that we can create and implement solutions. Soil protection and conservation starts with us. Making sustainable food choices, properly recycling dangerous materials like batteries, composting at home to reduce the amount of waste that enters landfills or managing antibiotic waste more responsibly, are just a few examples of how we can be part of the solution. On a larger scale, we need to promote sustainable agricultural practices in our communities.

Healthy soil is a precious, non-renewable commodity that is increasingly threatened by destructive human behaviours. We are responsible for the soils that provide us with food, water and air, and we need to take action today to ensure that we have healthy soils for a sustainable and food secure future.

Be the solution to soil pollution!