Indian Journal of Agricultural Sciences 71 (5) : 306–9, May 2001

Using organic wastes as compost and mulch for potato (*Solanum tuberosum*) in low water-retaining hill soils of north-west India

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Received: 1 February 2000

ABSTRACT

A field study was conducted during 1992–96 to evaluate the usefulness of Pamakani (*Eupatorium adenophorum* Sprengel) as compost and pine (*Pinus roxburgii* Sarg.)-needle as mulch in potato (*Solanum tuberosum* L.) on silty clay-loam, Typic Hapludalf having *p*H 5.6. The euopatorium compost contained 1.8% N, 0.05% P and 0.45% K compared with farmyard manure containing 1.62% N, 0.08% P and 0.32% K. The treatments included application of 20 tonnes/ha farmyard manure at planting of potato with no mulch and pine needle mulch @ 10 tonnes/ha and 2 levels of N (60 and 120 kg N/ha). Another treatment combination was application of 10 tonnes/ha eupatorium compost + 10 tonnes/ha farmyard manure and 2 levels of 60 and 120 kg N/ha. Potato tuber yield under treatment 10 tonnes/ha farmyard manure + 10 tonnes/ha eupatorium compost was similar to that recorded under both levels of N + 20 tonnes/ha farmyard manure, showing possibility of 50% substitution of farmyard manure with eupatorium compost. Pine-needle mulching maintained higher soil and plant water status, more roots and saved N equivalent to 60 kg/ha over no-mulch treatment. The practice also saved 1 irrigation and gave about 50% higher yield of autumn and 22% higher tuber yield of spring crop.

Key words: Water retention, Farmyard manure, Eupatorium compost, Pine-needle mulch, Soil and plant status, Potato tuber yield

Himachal Pradesh (30^0 22' to 33^0 12' N and 75^0 45' to 79^0 04' E) is one of the hilly states in north-west India with complex topography, high but erratic rainfall and sub-zero minimum soil temperatures during the winter. The soils are exposed to higher degree of erosion leading to shallow depth, degraded soil structure and coarser texture with abundance of stones and pebbles. This results in low retentivity of water and nutrients, poor soil-water relations, large infiltrability and low unsaturated hydraulic conductivity (Bhagat and Acharya 1987, Chenkual and Acharya 1990).

Potato *(Solanum tuberosum* L.), one of the cash crops of the state, is highly responsive to application of farmyard manure. Farmers invariably apply farmyard manure and supplement it with moderate quantity of chemical fertilizers. When farmyard manure is available, the potato crop receives priority to cereals. But of late, due to diversion of great amount of farmyard manure for growing vegetables and other cash crops, the potato growers are experiencing shortage of farmyard manure. The other alternative could be composting of the plant materials having no fodder value. Eupatorium (*Eupatorium adenophorum* Sprengel), an obnoxious and abundantly growing wild weed, available in plenty in hilly areas, is infesting grass and forest lands. It is rich in nitrogen (2%), bio-degradable and has no fodder value. Pine *(Pinus roxburgii* Sarg.) needles are another material that can be usefully utilized as mulch which favourably moderates the hydrothermal regime (Acharya and Sharma 1994). This material is otherwise collected and burnt to prevent fire-hazard in the forests. This may be efficiently used for mulching in potato as it is found in plenty around the potato-growing areas of the state.

Hence an experiment was conducted to study the possibility of substituting farmyard manure with eupatorium compost, prepared with cattle dung in a ratio of 10:1 (by weight), and evaluate the effect of mulching with pine-needles in ameliorating conditions of low water-retaining soil for growing potato.

MATERIALS AND METHODS

A field experiment with autumn (mid-September to mid-January) and spring (mid-January to May end) potato was conducted during 1992–96 on an Alfisol (Typic Hapludalf)

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at the experimental farm of the university at Palampur (1 300 m above mean sea-level and receiving 2 500 mm annual rainfall). The experimental soil (0–0.15 m depth) was silty clay-loam having 29% clay, 50% silt and 21% sand, bulk density 1.18 Mg/m^3; large (2.9 mm) mean weight diameter, *p*H 5.6, cation-exchange capacity 12 cmole (P^+)/kg soil and organic carbon 0.95%. It was low in available N and P and medium in available K. High basic intake rate (5 mm/hr) and abrupt decrease in moisture retention from saturation to 10 kPa suction coupled with dry spells from April to June and October to mid-December are the soil and climate related constraints for potato.

The treatments were: T_1, conventional cultivation + 20 tonnes/ha farmyard manure + 60 kg N/ha; T_2, T_1 but with 120 kg N/ha; T_3, T_1 but with 10 tonnes/ha farmyard manure + 10 tonnes/ha eupatorium compost; T_4, T_3 but with 120 kgN/ha; T_5, T_1 + pine-needle mulch @ 10 tonnes/ha at sowing; and T_6, T_2 + pine-needle mulch @ 10 tonnes/ha at sowing. The conventional cultivation included 2 ploughings up to 0.25 m depth followed by pulverization. 'Kufri Jyoti' potato was planted in ridges 0.45 m apart with 0.15 m plant-to-plant spacing and fertilized with 26 kg P/ha and 33 kg K/ha. The treatments, each in 5 m × 3 m plot, were replicated 4 times in randomized block design during autumn and spring seasons.

To prepare compost from *E. adenophorum*, a pit of the size 1.5 m × 1.5 m × 1.5 m was dug in August. A layer of succulent eupatorium (0.3m) was spread at the bottom of the pit. A layer of less rotten farmyard manure along with 40 g urea was spread over this layer. Likewise, 4 more layers of succulent eupatorium were spread in the pit with a layer of farmyard manure and urea between 2 layers. Thereafter pit was covered with loose soil. In September and November, the compost in the pit was worked up for proper mixing to ensure its proper decomposition. The so prepared compost contained 1.8% N, 0.05% P and 0.45% K compared with the farmyard manure containing 1.62% N, 0.08% P and 0.32% K.

Different parameters like xylem water potential, leaf-area index, root mass and water-use efficiency were determined during 1992, 1993 (autumn crops) and 1993, 1994 (spring crops) at tuber-enlargement stage (105 days after planting).

Xylem water potential

Xylem water potential was recorded using a portable pressure chamber (Waring and Cleary 1967). Observations were recorded from one of the replications during the mid-day (12.00-14.00 hr) under full sunlight at tuber enlargement stage. Three plants were randomly selected from each plot and xylem water potential was determined of fifth leaf from the top of each selected plant.

Leaf-area index

Number of plants in 1 m row length of randomly selected rows were counted. The leaf-area of all green leaves was recorded on area measurement system. The leaf-area index was calculated as leaf area : ground area ratio (Redford 1967).

Root mass

Root mass was determined for each treatment at tuber-enlargement stage, both during autumn and spring seasons. Plants were randomly selected from each plot and above-ground part was removed. The entire below-ground part was removed for root mass determination. The roots were washed free of soil and placed in a 1.0-mm sieve for a final wash in each case under a fine spray of water. Root mass was oven-dried (70°C) and expressed as root mass/plant.

Water-use efficiency

Mercury-water manometer tensiometers were installed at 0.15, 0.30, 0.45 and 0.60 m depths in one of the replications to monitor changes in soil water potential and hydraulic gradients during crop growth. Crop was applied 40 mm irrigation through flexible pipe each time when suction at 0.15 m depth reached around 25 kPa. Soil water content was measured gravimetrically for 0–0.15, 0–0.30, 0–0.45, 0–0.60 m depths at 1-week intervals and at planting and harvest of the crop.

Water-use efficiency (WUE) was calculated using the relations, WUE = Y/ET, where Y (kg/ha) is the potato tuber yield and ET (cm) is the evapotranspiration. ET was estimated from the relation.

$$ET = P + I + \Delta S_{t_1}^{t_2} \pm \int_{t_2}^{t_1} Vz\,dt$$

where P (cm) is the rainfall, I (cm) is the irrigation water, DS (cm) is the change in soil water storage between any 2 time intervals t_1 and t_2; and Vz (cm/d) is the vertical flux across the lower boundary of the root zone. Vertical flux (Vz), at 45 cm depth, was estimated from Darcy's law.

$$Vz = -K \frac{dH}{dZ}$$

where, K is the hydraulic conductivity of the adjoining field determined *in-situ* (Sharma and Acharya 1996) by internal drainage method (Hillel *etal.* 1972) and dH/dZ is the hydraulic head gradient.

RESULTS AND DISCUSSION

Xylem water potential

Xylem water potential values at 12.00 hr were not affected by half substitution of farmyard manure with eupatorium compost indicating that the compost was comparable to farmyard manure in maintaining plant water status (Table 1). Mulching (T_5, T_6) gave higher (–610, –590 kPa) xylem water potential than the remaining treatments (T_1 – T_4). Xylem water potential did not differ between 2 nitrogen levels.

Leaf-area index

Leaf-area index were comparable under compost and

Table 1 Xylem water potential at 12.00 hr, leaf-area index and dry root mass at tuber-enlargement stage of potato under mulch and compost treatments

Treatment	Autumn						Spring					
	Xylem water potential (–kPa)		Leaf-area index		Root mass (g/plant)		Xylem water potential (–kPa)		Leaf-area index		Root mass (g/plant)	
	1992	1993	1992	1993	1992	1993	1993	1994	1993	1994	1993	1994
T_1	715	670	2.21	2.91	2.62	2.19	1 090	910	3.10	2.90	3.15	3.38
T_2	720	665	2.30	3.15	2.71	2.41	1 045	880	3.23	3.12	3.47	3.51
T_3	680	710	2.35	2.85	2.73	2.50	1 065	890	2.97	3.10	3.23	3.27
T_4	690	680	2.47	3.22	2.58	2.46	1 070	880	3.20	3.25	3.42	3.62
T_5	610	515	3.20	3.90	3.25	3.47	910	730	3.87	4.15	4.31	4.07
T_6	590	520	3.39	4.46	3.67	4.08	890	705	4.24	4.38	4.89	4.70
CD (P=0.05)	45	52	0.39	0.48	0.37	0.56	56	61	0.42	0.55	0.45	0.58

T_1, Conventional cultivation + 20 tonnes/ha farmyard manure + 60 kg N/ha; T_2, T_1 but with 120 kg N/ha; T_3, T_1 but with 10 tonnes/ha farmyard manure + 10 tonnes/ha eupatorium compost; T_4, T_3 but with 120 kg N/ha; T_5, T_1 + pine-needle mulch @ 10 tonnes/ha at sowing; T_6, T_2 + pine-needle mulch @ 10 tonnes/ha at sowing

Table 2 Tuber yield, water-use and water-use efficiency of autumn potato under mulch and compost treatments

Treatment	Yield (tonnes/ha)					Water use (cm)		Water-use efficiency (kg/ha/cm)	
	1992	1993	1994	1995	Pooled average	1992	1993	1992	1993
T_1	8.82	9.95	9.57	5.50	8.46	18.5	20.6	476.8	483.0
T_2	9.45	11.39	11.82	6.77	9.86	19.3	20.1	489.6	566.7
T_3	8.82	9.23	10.07	5.33	8.37	19.6	19.9	450.0	463.8
T_4	10.22	11.78	13.15	5.37	10.13	19.9	20.3	512.6	560.3
T_5	10.20	15.96	13.91	10.67	12.69	18.4	18.6	554.6	867.4
T_6	10.38	17.31	16.37	14.02	14.52	18.7	18.9	555.1	915.8
CD (P=0.05)	0.51	1.37	1.57	1.05	1.19	NS	NS	70.4	109.7

T_1, Conventional cultivation + 20 tonnes/ha farmyard manure + 60 kg N/ha; T_2, T_1 but with 120 kg N/ha; T_3, T_1 but with 10 tonnes/ha farmyard manure + 10 tonnes/ha eupatorium compost; T_4, T_3 but with 120 kg N/ha; T_5, T_1 + pine-needle mulch @ 10 tonnes/ha at sowing; T_6, T_2 + pine-needle mulch @ 10 tonnes/ha at sowing; NS-not significant

Table 3 Tuber yield, water- use and water- use efficiency of spring potato under different treatments

Treatment	Yield (tonnes/ha)					Water use (cm)		Water-use efficiency (kg/ha/cm)	
	1992	1993	1994	1995	Pooled	1992	1993	1992	1993
T_1	9.67	12.94	15.91	14.65	13.30	46.5	42.3	208.0	305.9
T_2	10.67	14.08	17.77	18.09	15.15	48.6	43.6	219.5	322.9
T_3	9.11	13.14	16.87	14.92	13.51	45.9	41.9	198.5	313.6
T_4	10.45	15.80	17.53	16.96	15.19	47.0	44.0	222.3	359.1
T_5	11.34	16.01	19.56	18.41	16.33	42.3	38.7	268.0	413.7
T_6	13.00	19.22	21.02	20.11	18.34	43.1	39.3	301.6	489.1
CD (P=0.05)	0.96	2.04	1.42	1.24	1.46	2.0	2.4	42.3	65..3

T_1, Conventional cultivation + 20 tonnes/ha farmyard manure + 60 kg N/ha; T_2, T_1 but with 120 kg N/ha; T_3, T_1 but with 10 tonnes/ha farmyard manure + 10 tonnes/ha eupatorium compost; T_4, T_3 but with 120 kg N/ha; T_5, T_1 + pine-needle mulch @ 10 tonnes/ha at sowing; T_6, T_2 + pine-needle mulch @ 10 tonnes/ha at sowing farmyard manure treatments (Table 1). Mulch treatment with 60 kg N/ha (T_5) gave results similar to no mulch treatment with 120 kg N/ha (T_2). Treatment T_6 resulted in higher leaf area index by 47.4 and 41.6 % in autumn 1992 and 1993 and 31.3 and 40.4% in spring 1993 and 1994 respectively.

Root mass

Dry root mass except for the treatment of pine-needle mulching, did not differ under various treatments in the autumn and spring seasons. Pine-needle mulching provided cushioning effect against rain drops and irrigation allowing least disturbances to soil structure. Mulching at 60 kg N/ha (T_5) resulted in significantly higher root mass than the treatment with no mulch but with 120 kg N/ha (T_2). The root mass in mulch over no treatments increased by 30.0 and 64.0% in autumn and 39.0 and 27.6% in spring seasons of first and second years respectively.

Yield, water use and water-use efficiency

Tuber yields in treatments where half of the farmyard manure was substituted with compost (T_3 and T_4) were comparable at respective level of N to the treatment where no substitution of farmyard manure was effected (T_1 and T_2) during both the seasons (Tables 2, 3). For example, pooled yield data of 4 years showed that T_1 and T_3 treatments with 60 kg N/ha gave 8.46 and 8.36 tonnes/ha in autumn and 13.30 and 13.51 tonnes/ha in spring season, indicating that in the event of shortage of farmyard manure the eupatorium compost can replace it by 50% without affecting tuber yield.

The beneficial effect of pine-needle mulching (T_5 and T_6) on tuber yield was quite evident. Mulching with pine needle with 120 kg N/ha (T_6) increased the tuber yield (pooled data of 4 years) by 4.66 (autumn) and 3.19 (spring) tonnes/ha over T_2 (no mulch with 120 kg N/ha). Treatment T_5 (mulch with half N) gave similar or even higher (autumn) tuber yield than treatment T_2 (no mulch with full N), indicating a saving of N equivalent to 60 kg/ha through the former treatment. In general, higher N resulted in increasing the tuber yield in all the treatments. The tuber yields were higher under all treatments in spring than in autumn. Owing to more length of the growing season and favourable weather that prevails during spring than in autumn season. It was for this season that pine-needle mulch showed higher response in autumn than in the spring season due to moderation of hydrothermal regime for better plant growth. Sood and Sharma (1985) reported similar beneficial effects of mulching through improvement of soil environment resulting in better plant growth and tuber yield of potato.

Water-use and water-use efficiency (Tables 2,3) did not differ significantly between compost (T_3 and T_4) and farmyard manure (T_1 and T_2) treatments at respective N level. In general, pine-needle mulching with 60 kg N/ha (T_5) showed significantly higher water-use efficiency than no mulch with 120 kg N/ha (T_2). The mulching also resulted in saving of 1 irrigation equivalent to 40 mm. Lower crop water-use, moderation of hydrothermal regimes and increase in crop yield can be the reasons for higher water-use efficiency with mulching.

Thus, the problem of growing scarcity of farmyard manure for potato cultivation in shallow depth hill soils of the Himalayan region can be mitigated through additions of compost prepared from abundantly growing *Eupatorium adenophorum*. This will encourage its useful utilization with farmyard manure for growing potato and to enrich soils rather than its wasteful eradication from grass and forest lands. An application of pine-needle mulch proved effective in improving soil hydrothermal regime, favourable for better root growth and increased tuber yield and hence water- and nutrient-use efficiency.

ACKNOWLEDGEMENT

We are grateful to the Directorate of Water Management Research, Patna (ICAR), for the financial support provided to undertake this work.

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