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Research Paper

Crop productivity and soil health as influenced by organic sources of nutrients and weed management in rice (*Oryza sativa*)–potato (*Solanum tuberosum*)–Frenchbean (*Phaseolus vulgaris*) cropping system under irrigated condition

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ABSTRACT

A field experiment was conducted during 2015–16 and 2016–17 under different organic sources of nutrients and weed management in rice (*Oryza sativa* L.)–potato (*Solanum tuberosum* L.)–Frenchbean (*Phaseolus vulgaris* L.) cropping system with 6 sources of nutrients as main-plot treatments and 4 weed-management practices as sub-plot treatments. Among the organic sources of nutrients, application of 100% organics [100% recommended N (Rec. N) through different organic sources each equivalent to 1/3 of Rec. N, i.e. FYM + vermicompost + non-edible oil cake] + vesicular-arbuscular mycorrhiza (VAM), recorded significantly maximum individual crop yield, rice-equivalent yield (REY), system profitability, microbial population, soil organic carbon and available nutrients. Application of Indian mustard [*Brassica juncea* (L.) Czern.] seed meal @ 5 t/ha resulted in registered significantly higher yield of crops, REY, microbial population and soil organic carbon. However, the parameters like system profitability (303.85 and 364.03 ₹/ha/day), net returns (110,904 and 132,872 ₹/ha) and benefit : cost ratio (0.76 and 0.91) were recorded higher in the weed free plots.

Key words **:** Cropping system, Microbial population, Mustard seed meal, Organic sources of nutrients, Rice bran, Rice-equivalent yield

In rice–wheat cropping system, use of inorganic fertilizers and other chemicals is the most important and predominant practice in India in general and Jammu region of Jammu and Kashmir (U.T.) in particular.

It occupies 12.0 million ha productive lands in Indo-Gangetic plains and contributes about 25% of the national food production (Prasad, 2005). This system has sustained over years and brings together conflicting and complementary practices. Because of high productivity, stability and less risk factor, the wide adoption of this system will continue to play a major role in future planning to sustain self-sufficiency of foodgrains in the years to come (Singh *et al.,* 2012). But, now the productivity of both the crops have stagnated (Yadav, 1998) and factor productivity is declining year after year. Though the farmers realize much of their food security from this cropping system, its declining productivity needs urgent attention, which jeopardizes the farmers economic security to a considerable extent. To strengthen the economic security, it is imperative to intensify and diversify the existing rice–wheat system with some other high- value crops, viz. potato and frenchbean having greater economic worth using organic agriculture as a practice towards crop production. Inclusion of vegetables in the rice-based cropping systems has been suggested for higher productivity and profitability (Kachroo *et al*., 2014). Promotion of organic farming is being viewed as farming practice with distinct advantages of sustainability of crop production. Organic farming also permits the recycling of organic wastes, disposal of which could be difficult and expensive (Manjunatha *et al*., 2012). Though positive role of organic residues, including green-manures on soils and crops has been well documented (Rupela *et al*., 2006), in-

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formation on their use in location-specific cropping systems is lacking to understand the role of organic farming on soil health, crop productivity and sustainability. In view of this an experiment was conducted at Jammu on rice–potato–frenchbean cropping system with various organic sources of nutrients and weed-management practices, to find out the impact of various nutrient sources and weed-management practices on system productivity and soil properties.

MATERIALS AND METHODS

A field experiment was conducted during 2015–16 and 2016–17 on organic sources of nutrient and weed management in rice–potato–frenchbean system under irrigated condition at Research Farm, Farming System Research Centre, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir. The soil was clay loam, having *p*H 8.04, organic carbon 0.55%, available N, P and K of 220.40, 13.25 and 118 kg/ha respectively. The experiment was laid out in split-plot design, replicated thrice with 6 sources of nutrients in mainplot, viz. 50% recommended (Rec.) NPK through fertilizer + 50% N through farmyard manure (FYM) + inorganic source of micronutrients as per soil test, 100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake, 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM+ vermicompost + non-edible oil cake)+ marigold (Tagetes sp.) planted on border for potato crop as trap crop and bottle gourd [*Lagenaria sicerara* (Molina Standl.] was planted on border as trap crop for frenchbean during the subsequent seasons, 50 % Rec. N through vermicompost + biofertilizers for N + rockphosphate to substitute the P requirement + phosphate-solubilizing bacteria (PSB), 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM+ vermicompost + non-edible oil-cake) + VAM, 100 % Rec. NPK + secondary and micronutrients based on soil test through inorganic fertilizer, and 4 weed-management treatments in subplot, viz. weed-free, Indian mustard seed meal @ 5 t/ha, rice bran @ 4 t/ha and weedy check. The organic sources of nutrients used in the experiment were FYM (N, P, K 0.52, 0.23, 0.55%), vermicompost (N, P, K 2.32, 1.15, 1.50%), neem-cake (N, P, K 2.89, 0.84, 1.51%), rockphosphate (25.5% P) and biofertilizers such as *Azotobacter*, phosphate-solubilizing bacteria (PSB) and vesicular-arbuscular mycorrhiza (VAM). In case of organic nutrient management, all manures were applied before final land preparation for transplanting of rice and at planting of potato and frenchbean in furrows. The inorganic sources used were urea, single superphosphate and muriate of potash to supply N, P and K, respectively. The recommended doses of fertilizers for rice, potato and frenchbean were 30 : 20 : 10; 120 : 60 : 60 and 50 : 100 : 50 NPK (kg/ha) respectively. In case of inorganic nutrient management, full quantity of P and K were applied basal in all the crops and N was applied in split doses. In rice, 25% of N was applied basal, 50% top-dressed at tillering and rest 25% was applied at panicle initiation stage. In potato and frenchbean 50% of N was applied basal and rest N in 2 equal splits – 25 and 45 days after planting. The test varieties for rice, potato and frenchbean were ‘Pusa 1121’, ‘Kufri Sindhuri’ and ‘Contender’ respectively. Whereas, in case of weed management, Indian mustard seed meal and rice bran were applied as pre-plant incorporation (ppi) 10 days before transplanting/ planting of rice, potato and frenchbean. Standard agronomic management practices were followed for all crops. Crop yields were recorded at the end of each season and rice-equivalent yield (REY) was computed at the end of each cropping cycle. System profitability in terms of ₹/ha/day was worked out by net returns of the system divided by 365 days. The net returns were computed by deducting the total cost of cultivation from the gross returns as per treatments. Benefit : cost ratio was calculated by dividing the net returns with the cost of cultivation for different treatments. Soil samples were drawn at initial and at the end of each cropping cycle from a depth of 0–15 cm from each treatment and organic carbon (OC), N, P and K contents were analysed using standard procedures (Jackson, 1973). A portion of fresh soil samples were passed through a 2-mm sieve and stored at 4°C for determination of microbial population (Dhingra and Sinclair, 1993). Statistical analyses were carried out using standard methodology of split-plot design.

RESULTS AND DISCUSSION

Yield

The yields of individual crop (rice, potato and frenchbean) and system yield in terms of rice-equivalent yield (REY), during the both cropping cycles, were the highest with the 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N i.e. FYM + vermicompost + non-edible oil-cake) + VAM, which was statistically at par with 100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean and 100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake (Table 1). Combined application of FYM, vermicompost and neem-cake increased the adsorptive power of soil for cations and anions, particularly phosphates, nitrates and other micronutrients and their slow release during entire crop-growth period led to better translocation of photosynthates to the sink reflected by higher crop yield. Favourable soil conditions and availability of micro and major nutrients through the integrated use of different organic sources led to increased leaf surface area resulting in more photosynthesis, dry-matter accumulation and ultimately biomass yield (Verma *et al*., 2011 and Sharma and Subehia, 2014). REY was directly associated with the yield of respective crops in the sequence and so the application of 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake) + VAM enhanced the yield potential of crops which ultimately increased the rice equivalent yield of the sequence. Among the weed management treatments, application of Indian mustard seed meal @ 5 t/ha recorded significantly highest yield of rice, potato and frenchbean which was statistically at par with the application of rice bran @ 4 t/ha and weed-free treatment. Enhancement in the growth parameters under congenial environment provided by substantial reduction in intergeneric competition due to weed suppression and better translocation of carbohydrates for higher sink realization in these treatments. Higher nutrient content of Indian mustard seed meal led to enhanced N, P and K uptake also resulted in improvement in yield (Haramoto and Gallandt, 2004; Ullah *et al.*, 2008). Increase in the yield of respective crops (potato and Frenchbean) in sequence with the application of Indian mustard seed meal which ultimately increased the rice-equivalent yield.

System profitability

Application of 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake) + VAM recorded the highest system profitability followed by the application of 100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean (Table 2) was mainly because of higher productivity. Consequently, there was increase in system indicator through application of organics, enhancing the nutrient availability in soil by improving their fertility status (might be favourable improvement in soil physical, chemical and biological properties) responsible for augmentation of crop

Table 1. Effect of organic sources of nutrients and weed management on crop yield (t/ha) in rice–potato–Frenchbean cropping system

Treatment	Yield (t/ha)							
	Rice		Potato		Frenchbean		REY (t/ha)	
	2015	2016	2015–16	2016–17	2016	2017	2015–16	2016–17
Sources of nutrients								
50% Rec. NPK through fertilizer + 50% N through FYM + inorganic source of micronutrients as per soil test	3.61	3.75	12.66	12.81	3.77	3.86	13.05	11.29
100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake)	3.81	3.96	12.87	13.02	4.00	4.09	13.58	11.76
100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean	3.88	4.03	12.97	13.12	4.05	4.14	13.75	11.91
50% Rec. N through vermicompost + biofertilizers for N + rockphosphate to substitute the P requirement + PSB	3.34	3.47	12.43	12.57	3.50	3.58	12.39	10.70
100% organics + VAM	3.94	4.10	13.03	13.18	4.11	4.20	13.89	12.04
100% Rec. NPK + secondary and micronutrients based on soil test through inorganic fertilizer	3.37	3.50	12.45	12.60	3.53	3.61	12.46	10.77
SEm±	0.04	0.05	0.06	0.06	0.05	0.05	0.12	0.12
CD (P=0.05)	0.15	0.17	0.19	0.20	0.16	0.16	0.39	0.37
Weed-management								
Weed-free	3.82	3.97	13.73	13.94	4.06	4.19	14.03	12.17
Indian mustard seed meal @ 5 t/ha	3.92	4.09	13.83	14.06	4.19	4.33	14.30	12.43
Rice bran @ 4 t/ha	3.86	4.02	13.75	13.97	4.11	4.25	14.12	12.26
Weedy check	3.03	3.13	9.64	9.55	2.93	2.88	10.30	8.77
SEm±	0.04	0.04	0.05	0.05	0.05	0.05	0.11	0.10
CD (P=0.05)	0.11	0.13	0.14	0.15	0.14	0.15	0.30	0.28

Rec., Recommended; PSB, phosphate-solubilizing bacteria; VAM, vesicular arbuscular mycorrhyza

efficiency of system (Yadav *et al.*, 2013). Among the weed-management treatments, the highest system profitability was recorded in weed-free plots, whereas, the application of Indian mustard seed meal @ 5 t/ha recorded the lowest system profitability which was due to the highest cost of cultivation and lowest net returns.

Economics

System economics of different sources of nutrients and weed-management treatments was worked out to evaluate the most beneficial weed-management option in rice–potato–frenchbean cropping system. Application of 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N i.e. FYM + vermicompost + non-edible oil cake) + VAM recorded the maximum net returns which was owing to the highest gross returns under this treatment, whereas the benefit: cost (B:C) ratio was maximum with the application of 50% Rec. N through vermicompost + biofertilizers for N + rockphosphate to substitute the P requirement + PSB which might be due to the lowest cost of cultivation among the various organic nutrient treatments during both the years of cropping cycles (Table 2). Amongst weed-management treatments, the highest net returns and (B:C) ratio were obtained with weed-free treatment. Higher yields of crops (rice–potato–frenchbean) in weed-free treatment might have been responsible for the highest net returns and B : C ratio. However, the application of Indian mustard seed meal @ 5 t/ha and rice bran @ 4 t/ha recorded the lowest net returns and B : C ratio which was due to higher cost of cultivation in these treatments.

Soil microbial population

Application of 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake) + VAM though at par with the application of 100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean and 100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake recorded significantly highest population of bac-

Table 2. Effect of organic sources of nutrients and weed-management on system profitability and economics in rice–potato–frenchbean cropping system

Treatment	System profitability (₹/ha/day)		Economics			
			Net returns (₹/ha)		Benefit: cost ratio	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
Sources of Nutrients						
50% Rec. NPK through fertilizer + 50% N through FYM + inorganic source of micronutrients as per soil test	116.20	194.48	42,411	70,983	0.17	0.29
100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake)	213.38	314.24	77,885	114,696	0.28	0.41
100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean	220.20	322.90	80,372	117,860	0.28	0.42
50% Rec. N through vermicompost + biofertilizers for N + rockphosphate to substitute the P requirement + PSB	215.16	309.09	78,534	112,819	0.32	0.46
100% organics + VAM	229.85	333.88	83,894	121,868	0.30	0.43
100% Rec. NPK + secondary and micronutrients based on soil test through inorganic fertilizer	116.54	191.13	42,537	69,761	0.18	0.30
SEm±	–	–	–	–	–	–
CD (P=0.05)	–	–	–	–	–	–
Weed-management						
Weed-free	512.43	613.41	187,036	22,3895	1.15	1.37
Indian mustard seed meal @ 5 t/ha	–245.31	–139.84	–89,540	–51,041	–0.20	–0.11
Rice bran @ 4 t/ha	169.92	272.87	62,022	99,598	0.21	0.34
Weedy check	303.85	364.03	11,0904	132,872	0.76	0.91
SEm±	–	–	–	–	–	–
CD (P=0.05)	–	–	–	–	–	–

Rec., Recommended; PSB, phosphate-solubilizing bacteria; VAM, vesicular arbuscular mycorrhyza

teria, fungi and actinomycetes during both years of cropping cycle (Table 3). Increased organic carbon content of the soil owing to application of various organic nutrients over the years served as a source of energy for biological activity, thereby enhancing the density of microbes (Moharana *et al*., 2012). Further, most of the soil microorganisms are chemo-autotrophs, which require organic source of carbon as food and oxidation of organic substances provides energy which might be the reason in improving microbial population in soils applied with organics (Ingle *et al*., 2014). Different weed-management treatments also had a significant influence on population of microbes. Application of Indian mustard seed meal @ 5 t/ha recorded significantly highest population of bacteria, fungi and actinomycetes which was statistically at par with rice bran @ 4 t/ha. The increase in microbial population with the application of Indian mustard seed meal was probably because of the ability to effectively colonize and multiply in the rhizosphere and result in production of a wide spectrum of bioactive metabolites and also owing to the addition of organic matter which act as feed for the enhancement of microbial population in the soil (McSpadden and Gardener, 2007).

Organic carbon

The initial status of organic carbon of the experimental site was medium (0.55%). After each crop cycle, organic carbon was significantly influenced by different sources of nutrients and weed-management treatments (Table 4). Application of 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake) + VAM recorded significantly highest organic carbon which was statistically at par with 100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean and 100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake. Improvement in soil organic carbon content was observed in rice–potato cropping system owing to the use of paddy straw mulch, which acts as an organic source of nutrients (Sarangi *et al*., 2020). Addition of organic nutrient sources might have created

Table 3. Changes in microbial population under organic sources of nutrients and weed-management after crop cycle

Treatment	Microbial population in colony-forming units/g soil					
	Bacteria (×₹/10^6)		Fungi (×₹/10^3)		Actinomycetes (×₹/10^4)	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
Sources of nutrients						
50% Rec. NPK through fertilizer + 50% N through FYM + inorganic source of micronutrients as per soil test	51.58	53.14	31.02	33.65	38.69	41.55
100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake)	58.82	62.06	35.72	41.95	43.39	47.33
100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean	59.58	62.85	36.48	42.73	44.15	48.03
50% Rec. N through vermicompost + biofertilizers for N + rockphosphate to substitute the P requirement + PSB	55.85	59.05	33.75	38.94	41.42	45.40
100% organics + VAM	60.17	63.41	37.07	43.30	44.74	48.70
100% Rec. NPK + secondary and micronutrients based on soil test through inorganic fertilizer	48.44	47.29	27.88	23.42	35.55	32.28
SEm±	0.64	0.68	0.55	0.66	0.53	0.55
CD (P=0.05)	2.01	2.15	1.72	2.09	1.67	1.72
Weed-management						
Weed-free	49.75	51.12	28.67	32.14	36.34	38.79
Indian mustard seed meal @ 5 t/ha	61.76	64.86	38.66	42.19	46.33	49.01
Rice bran @ 4 t/ha	60.63	63.50	37.53	41.86	45.20	47.87
Weedy check	50.83	52.37	29.75	33.15	37.42	39.85
SEm±	0.44	0.49	0.47	0.47	0.41	0.42
CD (P=0.05)	1.25	1.40	1.35	1.35	1.17	1.22
Initial status	50.43	29.75	37.55			

Rec., Recommended; PSB, phosphate-solubilizing bacteria; VAM, vesicular arbuscular mycorrhyza

environment conducive for formation of humic acid, stimulated the activity of soil microorganisms resulting in an increase in organic carbon contents (Prasad *et al*., 2010). The higher build-up of organic carbon in the organic sources applied plots may be attributed to slower breakdown rate (less and constant mineralization rate) and increased above- and below-ground organic residues due to enhanced crop growth (Moharana *et al*., 2012). Among the weed-management treatments, though application of rice bran @ 4 t/ha was at par with application of Indian mustard seed meal @ 5 t/ha and weedy check plots, it recorded significantly highest organic carbon content which might be owing to the higher nutrient content of rice bran and Indian mustard seed meal and decomposition of weeds under weedy check plots which ultimately enhanced the organic carbon content of the soil.

Available nitrogen, phosphorus and potassium

The initial status of available N, P and K of the soil was 220.4, 13.2 and 118 kg/ha respectively. Available N, P and K content of soil after each crop cycle was significantly influenced by sources of nutrients (Table 4). Among the sources of nutrients, application of 100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake) + VAM though at par with 100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean and 100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake, recorded significantly highest available N and K. The increase in availability of N and K was on account of higher availability of mineral nutrients in soil owing to application of FYM, vermicompost and neem-cake. This could be ascribed to mineralization of manures, reduction in fixation and complexing properties of decomposition products of manures with micronutrients (Kanwar and Sharma, 2014). However, the application of 50% Rec. N through vermicompost + biofertilizers for N + rockphosphate to substitute the P requirement + PSB recorded significantly highest available P. Organic manures decomposition and solubilization of insoluble organic P fractions by PSB through release of various organic acids, result into a significant improvement in available P status in soil

Table 4. Changes in soil chemical properties under sources of nutrients and weed management after crop cycle

Treatment	Organic carbon (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2015–16	2016–17	2015-16	2016-17	2015–16	2016–17	2015–16	2016–17
Sources of nutrients								
50% Rec. NPK through fertilizer + 50% N through FYM + inorganic source of micronutrients as per soil test	0.62	0.67	247.34	254.61	14.74	14.87	135.00	147.16
100% organics (100% Rec. N through different organic sources each equivalent to one-third of Rec. N, i.e. FYM + vermicompost + non-edible oil-cake)	0.67	0.78	265.56	281.50	15.77	15.90	142.00	152.00
100% organics + marigold for potato on border as trap crop and bottle gourd as trap crop for frenchbean	0.68	0.76	269.23	282.44	15.82	16.95	144.38	153.91
50% Rec. N through vermicompost + biofertilizers for N + rockphosphate to substitute the P requirement + PSB	0.63	0.66	228.65	231.92	16.94	17.28	128.16	140.90
100% organics + VAM	0.70	0.78	274.17	286.83	15.85	16.80	145.17	156.12
100% Rec. NPK + secondary and micronutrients based on soil test through inorganic fertilizer	0.57	0.58	223.88	230.15	13.97	14.50	123.21	138.95
SEm±	0.009	0.010	5.10	5.34	0.40	0.45	1.47	1.73
CD (P=0.05)	0.030	0.033	16.08	16.83	1.26	1.43	4.62	5.47
Weed-management								
Weed-free	0.62	0.68	249.37	259.14	15.39	15.92	135.18	147.02
Indian mustard seed meal @ 5 t/ha	0.65	0.71	254.63	264.40	15.71	16.24	138.02	149.92
Rice bran @ 4 t/ha	0.65	0.71	252.15	261.92	15.56	16.09	136.69	148.53
Weedy check	0.64	0.70	249.73	259.50	15.41	15.94	135.38	147.22
SEm±	0.007	0.008	3.53	3.61	0.26	0.27	1.28	1.40
CD (P=0.05)	0.020	0.022	NS	NS	NS	NS	NS	NS
Initial Status	0.55	220.40	13.25	118				

Rec., Recommended; PSB, phosphate-solubilizing bacteria; VAM, vesicular arbuscular mycorrhyza

(Saravanan and Panneerselvam, 2014). Amongst weed-management treatments, statistically non-significant results were obtained with respect to available N, P and K during both the years of experimentation.

CONCLUSION

Based on the experimental results obtained from two years of study, it can be concluded that application of 100% Rec. N through different organic sources each equivalent to one-third of Rec. N i.e. FYM+ vermicompost + non edible oil cake + VAM application of Indian mustard seed meal @ 5 t/ha (organic weed management) produced significantly higher system productivity, profitability and REY besides showed improvement in physical, chemical and biological properties of soils to considerable and sustainable levels coupled with organically weed management practice i.e. weed free and application of rice bran @ 4 t/ha which were economically viable in rice-potato-frenchbean cropping system.

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