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EFFECT OF CROP ESTABLISHMENT METHODS AND WEED MANAGEMENT PRACTICES ON YIELD AND YIELD ATTRIBUTES OF RICE (*Oryza sativa* L.) UNDER TEMPERATE CONDITIONS OF KASHMIR

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ABSTRACT

Field experiments were conducted at the Faculty of Agriculture, SKUAST-Kashmir, Wadura, Jammu and Kashmir during *kharif* seasons of 2017 and 2018 to assess the effect of crop establishment methods and weed management practices on yield and yield attributes of rice (*Oryza sativa* L.) under temperate conditions of Kashmir. The experiment comprised of three crop establishment methods in main plots [transplanting (TPR), direct seeding (DSR) and system of rice intensification (SRI)] and seven weed management practices [butachlor @ 1500 g a.i. ha^{-1}, penoxsulam (@ 22.5 g *a.i.* ha^{-1}), pyrazosulfuran ethyl + pretilachlor (@ 15 and 600 g *a.i.* ha^{-1}), bensulfuron methyl + pretilachlor (@ 60 and 600 g *a.i.* ha^{-1}), twice cono-weeding/hand weeding, weed free and weedy check)] in sub-plots. The treatments were replicated thrice in a split plot design. The results revealed that SRI method of crop establishment gave significantly higher values for yield attributes *viz*., number of panicles (399.15) and grains panicle^{-1} (96.62) that resulted in higher grain (8.04 t ha^{-1}) and straw (9.88 t ha^{-1}) yield as compared to direct seeding and transplanted method. Among the weed management practices, the application of penoxsulam (@ 22.5 g *a.i.* ha^{-1}) gave significantly higher grain (8.24 t ha^{-1}) and straw (10.29 t ha^{-1}) yield as compared to other weed management practices, except weed-free and weedy check treatments. The average grain and straw yield increase with SRI was 24.11 and 23.62% over DSR and 10.47 and 12.23% over transplanted rice. Highest B: C ratio of 1.60 was realized under SRI with the application of penoxsulam @ 22.5 g *a.i.* ha^{-1}.

Keywords: Economics, intensification, penoxsulam, system of rice transplanting, yield

INTRODUCTION

Rice is cultivated in a wide range of ecosystems from irrigated to shallow lowlands, mid-deep lowlands and deep water to uplands. The method of crop establishment is one of the agronomical management practices which influences rice crop through its effect on growth and development. Transplantation is a common practice in rice cultivation in India. Transplanting rice seedlings into flooded fields gives the crop a major competitive advantage over weeds as the majority of weeds are suppressed by standing water (Pathak *et al*., 2011). However, immense labour and water is required to grow rice under puddle transplanted system; therefore, conventional puddle rice system is losing its sustainability and economic viability (Akbar *et al*., 2011). Direct seeding (DSR) is an alternative rice cultivation technology that offers faster and easier planting, reduces labour requirement, induces early crop maturity by 7-10 days, uses water more efficiently and leads to higher tolerance to water deficiency, less methane emission and often higher profit in areas with an assured water supply. Weed infestation is a major threat to yield and further expansion of DSR throughout the world (Naresh *et al*., 2011). Another method of establishment is system of rice intensification (SRI) which consists of a set of management practices that include transplanting of single seedling, widely spaced, young seedlings below 15 days age, mechanical weeding with a rotary push weeder that aerates the soil besides controlling weeds (Randriamiharisoa *et al*., 2006).

Herbicides are widely used to manage competing weeds as they are efficient, practical and cost-effective, particularly in the areas where labour is expensive. Butachlor has become popular in rice farmers of the state as pre-emergence herbicide for controlling the grass weeds, but its continuous use leads to a shift in weed flora from grass to sedges and broadleaf weeds as its application window is very narrow i.e. 0-3 days after transplanting (DAT) (Rajkhowa *et al*., 2006). Sulfonylurea herbicides *viz*., bensulfuron-methyl, metsulfuron-methyl, chlorimuron-ethyl, pyrazosulfuron-ethyl, bispyribac sodium, *etc*. are highly effective at very low rates of application, they are known as low dose high efficiency herbicides (LDHE herbicides). These herbicides show high herbicide potency at very low rates making them environmentally safe. Penoxsulam [acetolactate synthase (ALS) inhibitor] is a new promising herbicide for effective control of annual grasses, sedges and broadleaf weeds in rice (Bhat *et al.,* 2013).

As there is a meager scope of horizontal expansion of net cropped area, it becomes imperative to increase the vertical productivity through agronomical manipulations involving establishment methods, which still have the vast potential for realizing the potential yields of rice along with better control of weeds. Thus, the best establishment method along with timely and effective control of weeds is pivotal to augment the productivity of rice based cropping system. The present study was undertaken to assess the best crop establishment method and weed management practice for enhancing the productivity of rice under temperate conditions of Kashmir.

MATERIALS AND METHODS

The field experiment was conducted at SKUAST-Kashmir, Wadura Sopore, Jammu and Kashmir during *kharif* seasons of 2017 and 2018. The soil of experimental field was silty clay loam in texture, neutral in reaction (pH 6.9), medium in available N (380 kg ha^{-1}), available P (19.7 kg ha^{-1}) and available K (280 kg ha^{-1}) with medium organic carbon content (0.99%). The treatments consisted of three crop establishment methods [M_1 - transplanting (TPR), M_2 - direct seeding (DSR), M_3 - system of rice intensification (SRI)] in main plots and seven weed management practices in sub-plots [w_1 - butachlor (@ 1500 g *a.i.* ha^{-1}), w_2 - penoxsulam (@ 22.5 g *a.i.* ha^{-1}), w_3 - pyrazosulfuran ethyl + pretilachlor (@ 15 and 600 g *a.i.* ha^{-1}), w_4 - bensulfuron methyl + pretilachlor (@ 60 and 600 g *a.i.* ha^{-1}), w_5 - twice conoweeding/hand weeding, W_6 - weed free and w_7 - weedy check]. The treatments were replicated thrice in a split plot design. In SRI method, 12 days old seedlings cv. 'Shalimar Rice-4' were transplanted in the last week of May with a plant spacing of 25 cm x 25 cm, for direct seeded rice (DSR). The pre-germinated seeds were sown in rows 20 cm apart in well prepared plots on 17th May during both the years. However, in case of transplanting (TPR) method, nursery sowing was done with the same pre-germinated seeds on the same date and then 25 days old seedlings were transplanted at plant spacing of 20 cm x 10 cm. Well decomposed farm yard manure @ 10 t ha^{-1} was incorporated in the field uniformly before one month of sowing/transplanting. A uniform dose of NPK (120:60:30 kg ha^{-1}) was applied. The entire quantity of P and K and half of N was applied as basal at the time of transplanting while the remaining N was applied in two equal splits at active tillering and panicle initiation stages. Under SRI method all the principles were followed. Water management in both SRI and DSR was done in such a way that there was no continuous standing water during vegetative growth phase; while thin film of water was maintained during flowering to soft dough stage. Under TPR, 2-3 cm water was continuously maintained upto dough stage. Liquid herbicides, as per treatments, were applied with knapsack sprayer fitted with flat fan nozzle; whereas granular herbicides were mixed with sand and applied uniformly across the plot. The number of panicles falling in a quadrant of 0.25 m^2 were counted from each plot before harvest and the number was converted into m^{-2}. Panicle length of six randomly selected panicles from each plot was measured from neck node to the tip of panicle and then averaged and expressed in centimeters. Six randomly selected panicles from each plot were weighed and then averaged as weight $panicle^{-1}$ and expressed in grams. The number of spikelets from six panicles was counted from each plot and expressed as spikelets $panicle^{-1}$. The number of filled grains from each panicle was count, averaged and expressed as filled grains $panicle^{-1}$. Grain samples from each plot, collected separately at threshing, were dried properly. The 1000-grains from each of these samples were taken, their weights recorded and expressed in grams. The bundle weight of each net plot was recorded on electronic balance after sun-drying for 3-4 days after harvest in field and calculated on hectare basis [t ha^{-1}]. After proper threshing and cleaning the produce from each plot was sun-dried. The yield from each plot was recorded separately as kg $plot^{-1}$ and converted to t ha^{-1}. Straw yield of each plot was computed by deducting the grain yield from the respective biological yield and expressed in t ha^{-1}. The crop was harvested during 2nd week of October in both the years. Weeds falling in a quadrant of 0.25 m^2 were uprooted from each plot at harvest, identified, counted and expressed as weed m^{-2}. Weeds uprooted from each plot for weed count were washed, sun dried and then oven dried at 60-65°C for 48 h to a constant weight. The weight was expressed in grams and then converted to g m^{-2}. Weed control efficiency for different weed control treatments was worked out as per the following formula:

$$WCE = \frac{WDC - WDT}{WDC} \times 100$$

Where, WCE = weed control efficiency, WDC = weed dry weight in control plot; WDT = weed dry weight in treated plot

The economics of various treatments was worked out on the basis of grain and straw yield ha^{-1}. The cost of input and output was estimated as per the prevailing market rates. The benefit: cost ratio (returns per rupee invested) was determined as:

$$\text{Benefit cost ratio} = \frac{\text{Net returns}}{\text{Total cost of cultivation}}$$

The data was statistically analyzed as per Cochran and Cox (1963). The significance of ‘F’ and ‘t’ was tested at 5% level of significance. The critical difference values were determined when ‘F’ test was significant. Analysis of data was done by using OP Stat software (Anonymous, 2012).

RESULTS AND DISCUSSION

Effect of crop establishment methods and weed management practices on yield attributes and yield

Crop establishment methods exhibited significant effect on yield attributes of rice. Maximum number of panicles (399.15) was observed in SRI method, followed by transplanting (381.95). SRI significantly increased panicle length, panicle weight and spikelets $panicle^{-1}$ over transplanted and direct seeded rice, and the magnitude of superiority with respect to panicle length over transplanted and direct seeded rice was 7.85 and 18.08%, respectively. Significantly higher number of grains $panicle^{-1}$ was observed in SRI as compared to the DSR and transplanting (Table 1). SRI recorded 96.62 grains $panicle^{-1}$ which was 23.3 and 11.0% higher than DSR and transplanting methods, respectively. Under SRI there is a wider spacing and less competition between plants, which promotes more profuse growth of roots and produces effective tillers. Moreover, SRI helps in more root length

Table 1: Effect of different crop establishment methods and weed management practices on yield attributes of rice (pooled data of 2017 and 2018)

Treatments	Panicle density (No. m^{-2})	Panicle length (cm)	Panicle weight (g)	Spikelets panicle^{-1}	Filled grains panicle^{-1}	1000 grain weight (g)
Crop establishment methods						
Transplanting	381.95	23.23	2.58	109.05	85.99	23.63
Direct seeding	347.55	20.65	2.24	87.85	74.07	23.00
System of rice intensification	399.15	25.21	2.83	120.65	96.62	25.16
SEm±	4.06	0.09	0.07	3.12	2.52	0.75
$CD_{0.05}$	12.20	0.29	0.21	9.38	7.56	ns
Weed management practices						
Butachlor (@ 1500 g *a.i.* ha^{-1})	350	22.54	2.37	102.50	78.95	23.20
Penoxsulam (@ 22.5 g *a.i.* ha^{-1})	413.4	25.33	2.85	115.95	95.66	24.86
Pyrazosulfuron-ethyl + Pretilachlor (@ 15 and 600 g *a.i.* ha^{-1})	394.75	23.33	2.68	111.15	89.63	24.37
Bensulfuron-methyl + Pretilachlor (@ 60 and 600 g *a.i.* ha^{-1})	378.9	23.01	2.50	107.60	86.00	24.06
Twice Conoweeding/handweeding (15 and 30 DAS/DAT)	365.15	22.79	2.47	106.85	82.51	23.78
Weed free	426.8	25.07	3.03	121.35	102.93	25.59
Weedy check	289.5	19.10	1.96	75.50	54.79	21.74
SEm±	4.02	0.16	0.04	1.85	1.66	0.24
$CD_{0.05}$	12.08	0.48	0.12	5.55	4.99	0.73

density of crop, which produces greater xylem exudates and transports these to the shoot at faster rates. These features contribute to the maintenance of high chlorophyll levels, enhance fluorescence and photosynthesis rates of the leaves and support more number of effective tillers m^{-2} than in more disturb soil. These results are in close conformity with those of Geethalaxmi *et al.* (2011) and Shao-hua *et al.* (2002). However, the effect of crop establishment methods on 1000-grain weight of rice was found non-significant. This may be due to the fact that test weight is a genetic character of the crop. The results are in close conformity with those of Yadav and Saha (2014).

Among the weed management practices, the maximum number of panicles (413.4) were found in penoxsulam @ 22.5 g *a.i.* ha^{-1} treatment, and least (289.5) in weedy check. The superiority exhibited by penoxsulam treatment @ 22.5 g *a.i.* ha^{-1} over weedy check in increasing the panicle number was 29.97%. Maximum panicle length of 25.33 cm was recorded in penoxsulam @ 22.5 g *a.i.* ha^{-1} treatment. The application of penoxsulam @ 22.5 g *a.i.* ha^{-1} showed significantly highest panicle weight of 2.85 g, number of filled grains, spikelets panicle^{-1} and 1000-grain weight over other weed management practices (Table 1). The superiority with respect to filled grains panicle^{-1} exhibited by penoxsulam @ 22.5 g *a.i.* ha^{-1} treatment over butachlor @ 1500 g *a.i.* ha^{-1} was 17.46%, respectively. This may be ascribed to the fact that weed-free and penoxsulam @ 22.5 g *a.i.* ha^{-1} treated plots might have absorbed the applied nutrients and other growth factors due to less competition between crop and weeds, and hence all the yield attributing characters acquired higher values (Bhat *et al*., 2011).

Grain and straw yield of rice differed significantly during both the years of experimentation (Table 2). SRI method of crop establishment gave significantly higher grain yield (8.04 t ha^{-1}), followed by transplanting method (7.13 t ha^{-1}), while lowest grain yield of 6.12 t ha^{-1} was noticed in DSR. The crop established by SRI method provided a yield advantage of 23.88% over DSR and 11.31% over transplanting methods, respectively. Hugar *et al.* (2009) also reported higher grain yield of rice under SRI. SRI method also gave significantly higher straw yield than DSR and transplanting methods. The higher grain and straw yield realized with SRI method may be due to transplanting of

Table 2: Effect of different crop establishment methods and weed management practices on yield ($t\ ha^{-1}$) of rice (pooled data of 2017 and 2018)

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
Crop establishment methods				
Transplanting	7.13	9.04	16.17	44.09
Direct seeding	6.12	8.16	14.28	42.86
System of rice intensification	8.04	9.88	17.93	44.86
SEm±	0.25	0.29	0.37	0.23
$CD_{0.05}$	0.77	0.87	1.12	0.69
Weed management practices				
Butachlor (1500 g *a.i.* ha^{-1})	6.24	8.45	14.69	42.44
Penoxsulam (@ 22.5 g *a.i.* ha^{-1})	8.24	10.29	18.52	44.48
Pyrazosulfuron-ethyl + Pretilachlor (@ 15 & 600 g *a.i.* ha^{-1})	7.68	9.41	17.10	44.92
Bensulfuron-methyl + Pretilachlor (@ 60 & 600 g *a.i.* ha^{-1})	7.36	9.20	16.57	44.45
Twice conoweeding/handweeding (@ 15 & 30 DAS/DAT)	7.10	8.84	15.95	44.55
Weed free	9.15	10.97	20.11	45.47
Weedy check	4.25	6.28	10.52	40.33
SEm±	0.29	0.19	0.39	0.21
$CD_{0.05}$	0.88	0.57	1.19	0.62

seedlings at younger age which preserves a potential for more tillering and rooting. Further, wide spacing in square pattern (25 cm x 25 cm) provides more room for both canopy and root growth and for subsequent grain filling. The increase in grain yield under SRI method may be attributed to larger root volume, profuse and strong tillers with longer panicles, more and well filled spikelets with higher grain weight. Higher grain yield of rice under SRI was also recorded by Satyanarayana and Babu (2004). Comparable yields in rice through alternate systems of crop establishment with that of transplanting has been reported by Mankotia *et al.* (2009) and Mahajan *et al.* (2012).

Among the weed control treatments, penoxsulam @ 22.5 g *a.i.* ha^{-1} gave significantly higher grain (8.24 t ha^{-1}) and straw (10.29 t ha^{-1}) yield over weedy check and other weed control treatments (Table 2). Penoxsulam treatment @ 22.5 g *a.i.* ha^{-1} realized 24.27% higher grain yield and 17.88% higher straw yield over butachlor @ 1500 g *a.i.* ha^{-1}, respectively. This could be attributed to the fact that reduction in weed growth with the herbicide application allowed the crop to get adequate nutrient supply resulting in higher leaf-area index and thus more photosynthates, which, in turn, contributed to the sink resulting in higher grain and straw yield (Shan *et al*., 2012; Jabran *et al*., 2012).

Effect of crop establishment methods and weed management practices on weeds

The major grassy weeds observed were *Echinochloa crusgalli, Echinochloa colona* and *Cynodon dactylon.* Broad-leaved weeds observed were *Marsilea qudrofolia, Ammania baccifera, Potamogeton distinctus* and *Monochoria vaginalis;* whereas, the sedges included *Fimbristylis, Cyperus iria,* and *Cyperus defformis.* Significantly lower density was recorded in transplanted method at 60 DAT/DAS over SRI and DSR methods (Table 3). The superiority exhibited by transplanted rice in reducing weed densities over SRI and direct-seeded rice were 11.62 and 40.79%, respectively. Weed dry matter was significantly reduced under transplanted rice as compared to the SRI and DSR methods. SRI, in turn, was significantly superior to direct-seeded rice at all growth stages of crop. Superiority exhibited by transplanted rice in reducing the weed dry matter over SRI and DSR at 60 DAT/DAS was 8.98 and 42.9%, respectively (Table 3). Continuous submergence of transplanted crop effectively suppressed the weed population and weed seed germination under transplanted rice. The results are in agreement with Subramanian *et al.* (2007). Effective weed control was observed with the application of penoxsulam @ 22.5 g ha^{-1} during both the years. The superiority exhibited by penoxsulam @ 22.5 g

Table 3: Effect of crop establishment methods and weed management practices on weed density (No. m^{-2}), dry weed biomass (g m^{-2}) and weed control efficiency (%) (pooled data of the years 2017 & 2018)

Treatments	Weed density (No. m^{-2}) at 60 DAT	Weed dry weight (g m^{-2}) at 60 DAT	Weed control efficiency (%) at 60 DAT
Crop establishment methods			
Transplanting	4.18 (17.00)	5.27 (27.25)	75.13
Direct seeding	7.06 (49.40)	9.23 (84.75)	71.07
System of rice intensification	4.73 (21.90)	5.79 (33.05)	75.29
SEm±	0.03	0.02	0.40
$CD_{0.05}$	0.08	0.05	1.58
Weed management practices			
Butachlor (@ 1500 g *a.i.* ha^{-1})	6.25 (38.60)	7.51 (55.90)	57.63
Penoxsulam (@ 22.5 g *a.i.* ha^{-1})	4.27 (17.70)	5.71 (32.10)	76.52
Pyrazosulfuron-ethyl + Pretilachlor (@ 15 & 600 g *a.i.* ha^{-1})	4.59 (20.60)	5.98 (35.30)	73.96
Bensulfuron-methyl + Pretilachlor (@ 60 & 600 g *a.i.* ha^{-1})	4.69 (21.50)	6.31 (39.30)	70.32
Twice conoweeding/handweeding (@ 15 & 30 DAS/DAT)	4.90 (23.50)	6.80 (45.70)	64.56
Weed free	1.00 (00.00)	1.00 (00.00)	100.00
Weedy check	9.21 (84.30)	11.42 (130.00)	00.00
SEm±	0.04	0.03	0.36
$CD_{0.05}$	0.13	0.10	1.03

DAS/DAT: days after transplanting sowing; Figures in parentheses are original values; Data subjected to $\sqrt{x+1}$ transformation

ha^{-1} at 60 DAT/DAS over weedy check and butachlor @ 1500 g ha^{-1} was 53.63 and 31.68%, respectively. Penoxsulam @ 22.5 g ha^{-1} significantly reduced the weed dry matter and the reduction in weed dry matter at 60 DAT/DAS by penoxsulam @ 22.5 g ha^{-1} over weedy check and butachlor @ 1500 g ha^{-1} was 50 and 23.96%, respectively. This might be due to the fact that herbicides not only exhibited significantly lesser toxicity to rice seedling but controlled the weeds very efficiently. The study established that penoxsulam is an effective post-emergence herbicide against a wide weed flora and shows selectivity to the rice crop. Penoxsulam is a member of the chemical family of triazolopyrimidine sulphonamide with ALS (acetolactate synthase) inhibition as its mode of action. It has a favourable toxicological and environmental profile. The results were in conformity with Bhat *et al*. (2011). Penoxsulam 22.5 g ha^{-1} recorded weed control efficiency of 76.52% (Table 3). Reduction in weed biomass due to effective weed control measures had resulted in higher weed control efficiency.

Economics

The economics was worked out taking into consideration the cost of production for each treatment and the corresponding marketable yield with prevalent prices per unit output. The pooled data on economic analysis of treatments is presented in Table 4. It revealed that the highest gross returns (₹ 217159.3) and net returns (₹ 133769.3) were realized under SRI method with the application of penoxsulam (@ 22.5 g *a.i.* ha^{-1}) during both the years. The highest B: C ratio of 1.60 was also with the same combination and the lowest B:C ratio (0.32) was realized in the combination of direct seeding method with weedy check. This might be due to the fact that, SRI enhanced yield because of higher water infiltration and storage capacity and less erosion that resulted in maximum benefit, contributing higher benefit cost ratio (Rani and Sukumari, 2013). Among the different herbicides used penoxsulam @ 22.5 g *a.i* ha^{-1} provided nearly a weed free situation at the critical growth stages of crop growth and enhanced the competitive ability of the rice crop. The results are in line with that

Table 4: The economics of crop establishment methods and weed management practices in rice (Pooled over 2017 and 2018)

Treatment combinations	Total cost of cultivation (₹)	Gross returns from grain yield (₹)	Gross returns from straw yield (₹)	Total returns (₹)	Net returns (₹)	B:C ratio
M_1W_1	77615	80270.7	84006	164276.7	86662	1.12
M_1W_2	79165	107978.0	94449	202427.0	123262	1.56
M_1W_3	78735	103688.0	91635	195323.0	116588	1.48
M_1W_4	78735	99792.3	88725	188517.3	109782	1.39
M_1W_5	81465	95740.7	85911	181651.7	100187	1.23
M_1W_6	85465	111583.3	97275	208858.3	123393	1.44
M_1W_7	77465	54340.0	52941	107281.0	29816	0.38
M_2W_1	69715	67682.3	75411	143093.3	73378	1.05
M_2W_2	71265	95355.0	84897	180252.0	108987	1.53
M_2W_3	70835	91303.3	82077	173380.3	102545	1.45
M_2W_4	70835	87247.3	80175	167422.3	96587	1.36
M_2W_5	73565	83217.3	77331	160548.3	86983	1.18
M_2W_6	77565	99645.0	84690	184335.0	106770	1.38
M_2W_7	69565	46345.0	45390	91735.0	22170	0.32
M_3W_1	81840	87351.3	91794	179145.3	97305	1.19
M_3W_2	83390	115834.3	101325	217159.3	133769	1.60
M_3W_3	82960	112298.3	98559	210857.3	127897	1.54
M_3W_4	82960	107835.0	95763	203598.0	120638	1.45
M_3W_5	85690	103848.3	93039	196887.3	111197	1.30
M_3W_6	89690	119946.7	134355	254301.7	164612	1.84
M_3W_7	81690	66711.7	61695	128406.7	46717	0.57

M_1 = Transplanting, M_2 = DSR, M_3 = SRI, W_1 = Butachlor, W_2 = Penoxsulam, W_3 = Pyrazosulfuran ethyl + Pretilachlor, W_4 = Bensulfuran methyl + Pretilachlor, W_5 = Twice cono-weeding/Hand weeding, W_6 = Weed free, W_7 = weedy check

of Bhat *et al*. (2011).

Conclusion: From the study it may be concluded that SRI method is a better remunerative method of crop establishment than transplanting and direct seeding methods in terms of grain yield. Further, weeds in rice can be effectively managed by the application of penoxsulam @ 22.5 g *a.i.* ha^{-1} and being superior to commonly used butachlor may be recommended for use by the farmers to boost productivity of rice in Kashmir valley.

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