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Influence of integrated plant nutrition system on growth, development and yield of rice in rice-wheat cropping system

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Abstract
Long-term use of organic and chemical inputs has a tremendous impact on growth, development and yield of crop. Farm yard manure (FYM), wheat cut straw (WCS) and green manure (GM) were used for many years old rice (*Oryza sativa* L.) -wheat (*Triticum aestivum* L.) cropping system to determine various effects on growth, development and yield. Application of chemical fertilizers alone or in combination with organic manures found increased grain yield of rice significantly over control. Highest number of shoots/m^2 and plant height (cm) of rice were recorded under (T_6) where 50% NPK through fertilizers and 50% N through FYM to rice and 100% NPK through fertilizers to wheat were applied. Heading in rice was earliest in T_6 (50% NPK and 50% N (FYM) to rice with 100% NPK to wheat) and was too late in control (T_1) during both the years. Crop maturity was significantly late under T_1 (control) when no fertilizers and manures were applied. On an average in rice where 50% NPK in combination with 50% N (FYM) was applied to rice was found to be the best treatment for getting higher productivity and profitability.

Keywords: growth, integrated plant nutrition system, rice-wheat cropping system, rice yield

Introduction
Of the 30 major cropping systems identified in India (Yadav and Prasad 1998) [27], rice-based cropping system is the most predominant in India occupying around 10.5 m ha area (Sharma 2009) [19]. Among cereals, rice and wheat are the most important crops, which account for about 60% of world's human energy requirement. This system contributes about 75% of the nation's total food grain production, thus forms the backbone of food security (Lathwal *et al.* 2010) [7]. Rice is the staple food for more than half of world's population and almost 70% of Indians (Tripathy *et al.* 2017) [24]. In India, total area under rice is 43.9 million hectares with production of 104.3 million tonnes of respective crops (Anonymous 2016) [1]. It has tremendously helped the socio-economic development of the rural population in India. Farmers realize much of their food security from this cropping system. Besides food security, the low production levels jeopardize farmers' economic security to a considerable extent. The top most priority to meet the food demand of expanding human population is to increasing productivity of main grain crops. To strengthen the economic conditions of the farmers, it is imperative to sustain the productivity of this system. However, fertilizers are the kingpin in increasing crop productivity. But in case of intensive cultivation, growing exhaustive crops, use of unbalanced and inadequate fertilizers accompanied by restricted use of organic manures and bio fertilizers have made the soils not only deficient in the nutrients, but also deteriorated in its health resulting in decline in crop response to the recommended dose of N-fertilizer. Under such a situation, integrated nutrient management (INM) has assumed a great importance and has vital significance for the maintenance of soil productivity. The concept of Integrated Nutrient Management (INM) takes into consideration the nutrient cycle involving soils, crops and livestock, nutrient deficiencies, organic recycling, conjunctive use of organic manures and mineral fertilizers and biological nitrogen fixing potential. INM involving the use of fertilizers along with organic sources of nutrient such as FYM, GM and crop residues is a precious research outcome to restore productivity. INM, the managerial aspect of integrated plant nutrition system (IPNS) is more vital in sustaining increased productivity (Yadav and Kumar 2009) [26]. The integrated use of organic manures and inorganic fertilizers can help to maintain optimum crop yields and long-term soil productivity (Puli *et al.* 2016) [13].

Farmers mostly use organic sources alone but their availability as per the requirement is a problem. The importance of leguminous green manure (GM) crops in improving soil fertility and soil physical properties has received increasing attention in recent past (Ray and Gupta 2001) [14]. Organic manures, particularly GM and farmyard manure (FYM), not only supply macronutrients but also meet the requirement of micronutrients, besides improving soil health.

Materials and Method

Experimental Details

Geographically, the experimental site is situated at 32° 6' N latitude, 76° 3' E longitude and 1290.8 m altitude in North Western Himalaya in the Palam Valley of Kangra district of Himachal Pradesh. The present study was undertaken during 2014 and 2015 in an ongoing long-term experiment which was initiated during kharif 1991 with rice - wheat cropping system at the Bhadiarkhar farm of CSK HPKV Palampur University (32º 6´ N latitude, 76º 3´ E longitude and 1223.7 m altitude). Palampur represents the sub-temperate humid zone of Himachal Pradesh which is characterized by mild summers and cool winters. The area receives a very high rainfall during monsoon and medium to high rainfall with an occasional snowfall during winters. Agro-climatically, the experimental site falls in the sub-temperate zone in the mid-hills of Shivalik ranges of Himalayas which is endowed with mild summers and cool winters along with high rainfall during south-west monsoons. Average rainfall at the experimental site is 2600 mm/annum, major portion of which (80%) is received during monsoon season (June to September).

The soil of the experimental site was silty clay loam in texture, acidic in nature (pH 5.5), high in available nitrogen (675 kg/ha), medium in available P (22 kg/ha) and K (221 kg/ha) with CEC of 11.5 c mol (p±). Taxonomically the soils of the region are classified as 'Typic Hapludalf'. The field experiment was established with rice and wheat as test crops. In this field investigation, 12 treatments were evaluated in a randomized block design with four replications which are as follows (Table 1):

Table 1: Details of treatments in rice-wheat cropping system

Treatment	Kharif	Rabi
T_1	Control (No fertilizer, no manures)	Control (No fertilizer, no manures)
T_2	50% NPK* through fertilizer	50% NPK through fertilizer
T_3	50% NPK through fertilizer	100% NPK through fertilizer
T_4	75% NPK through fertilizer	75% NPK through fertilizer
T_5	100% NPK through fertilizer	100% NPK through fertilizer
T_6	50% NPK+50% N through farmyard manure (FYM)	100% NPK through fertilizer
T_7	75% NPK+25% N through farmyard manure	75% NPK through fertilizer
T_8	50% NPK+50% N through wheat cut straw (WCS)	100% NPK through fertilizer
T_9	75% NPK+25% N through wheat cut straw	75% NPK through fertilizer
T_{10}	50% NPK+50% N through green manure (GM)	100% NPK through fertilizer
T_{11}	75% NPK+25% N through green Manure	75% NPK through fertilizer
T_{12}	Farmers' practice (40% NPK+ 5t FYM/ha)	Farmers' practice (40% NPK through fertilizer)

*NPK - Through chemical fertilizer

In farmers' practice, FYM 5 t/ha was applied along with 40% NPK to rice followed by 40% NPK to wheat. The recommended (100%) dose of nutrients in rice and wheat was 90:40:40 and 120:60:30 kg N, P_2O_5 and K_2O/ha, respectively. Samples of organic sources were analyzed for N, P and K contents as per the methods before application in rice season and data have been reported in Table 2. Quantity of farmyard manure (FYM), wheat cut straw (WCS) and *ex-situ* green manure (GM) used in the experiment were worked out on field weight basis and incorporated before transplanting of rice. In rice, half of N and entire quantity of P and K were applied as basal dose through urea, single superphosphate and muriate of potash, respectively. The remaining half dose of N was applied at tillering stage. The organics *viz.*, FYM, WCS and Dhaincha/Sunhemp as GM were applied to rice crop only in the specified treatments. Entire amount of P and K were applied as basal dose and remaining 2/3rd dose of N in two splits at tillering and grain filling stage through urea, superphosphate and muriate of potash, respectively.

Table 2: Nitrogen, phosphorus and potassium contents (%) of organics (dry wt. basis)

Organics	N	P	K
FYM (Cow dung manure)	1.20	0.225	1.013
Wheat cut straw	0.46	0.048	1.300
Green manure (Dhaincha)	2.40	0.163	1.556

Crop Studies

Growth Studies

The observations on growth characters *viz.*, plant height and number of shoots (plant population) was recorded at monthly interval in rice crop. For these observations, one outer row on all sides was left as border rows and the following one row on both sides were used for dry matter accumulation studies. The procedures adopted for recording of observations on various growth parameters are described here as under:

a. Plant height

Height of five randomly selected hills in the net plot area were measured from the soil surface to the tip of tallest leaf or tip of rice panicle and mean height was worked out.

b. Number of shoots

Five hills were randomly marked with sticks in the net plot area and shoots were counted. Total numbers of shoots in metre row length was counted at intervals mentioned as above and mean value was converted to number of shoot/m^2 of rice and wheat.

Development studies (Phenophases)

a. Days to heading/flowering

Complete emergence of panicles out of the top leaf sheath was considered to be heading/flowering stage. When 75% of the shoots in the observational unit (5 hills) borne the panicle, the stage was considered to be complete and the data were reported as days after transplanting. The number of days after sowing was worked out as days taken for heading/flowering.

b. Days to maturity

Five panicles were randomly selected from the sampling rows. When 75% of the grains attained hard dough stage, the date was noted as maturity stage and number of days required were worked out from the date of transplanting.

Result and Discussion

Crop-weather interaction

The performance of any crop depends on the interaction between genetic and environmental factors. The environment plays an important role in influencing growth, development and ultimately the yield of a crop. Among the various environmental factors, weather parameters like ambient temperature, rainfall, sunshine hours and relative humidity play an important role. Photo periodically, rice is a short-day plant which needs a hot and humid climate. It is best suited to regions which have high humidity and an assured supply of water. If a region receives about 1400-1800 mm/annum well distributed rainfall during the crop growth period, it will be sufficient for a successful crop of rice. It prefers brighter and prolonged sunshine for enhanced photosynthetic activity and higher yield, and therefore, should receive more than 300 sunshine hours during the last 45 days before harvest (Yoshida 1981) [28]. The temperature required for germination is in the range of 18 to 40 °C. The average temperature required throughout the life period of the crop ranges from 21 to 35 °C (Ghadirnezhad and Fallah 2014) [4]. At the time of tillering the crop requires optimum temperature of about 25 to 31 °C. Temperature required for an thesis is in the range of 30 to 33°C and for ripening between 20 to 29°C (Yoshida 1978) [29]. During the crop growing seasons of 2014 and 2015, the temperature was well within the range for the successful cultivation of rice as suggested by Ghadirnezhad and Fallah (2014) [4] (Fig. 1).

The average monthly maximum temperature during *kharif* 2014 and 2015 (June to October) ranged between 24.3 to 31.3°C and 21.8 to 29.2°C, respectively. The average monthly minimum temperature ranged between 13.0 to 19.7°C and 9 to 19.1°C in 2014 and 2015, respectively. The crop experienced well distributed rainfall of 1334 mm and 1988 mm in first and second year, respectively, which was well close to the range as suggested by Yoshida (1981) [28]. The highest monthly total rainfall of 622.6 mm and 837.5 mm, was resulted in July and August during the first and second year, respectively. The mean relative humidity during the crop season of first year ranged between 55 to 86% whereas during the second year was between 60 to 90% which was optimum for rice crop (Reddy 2004).

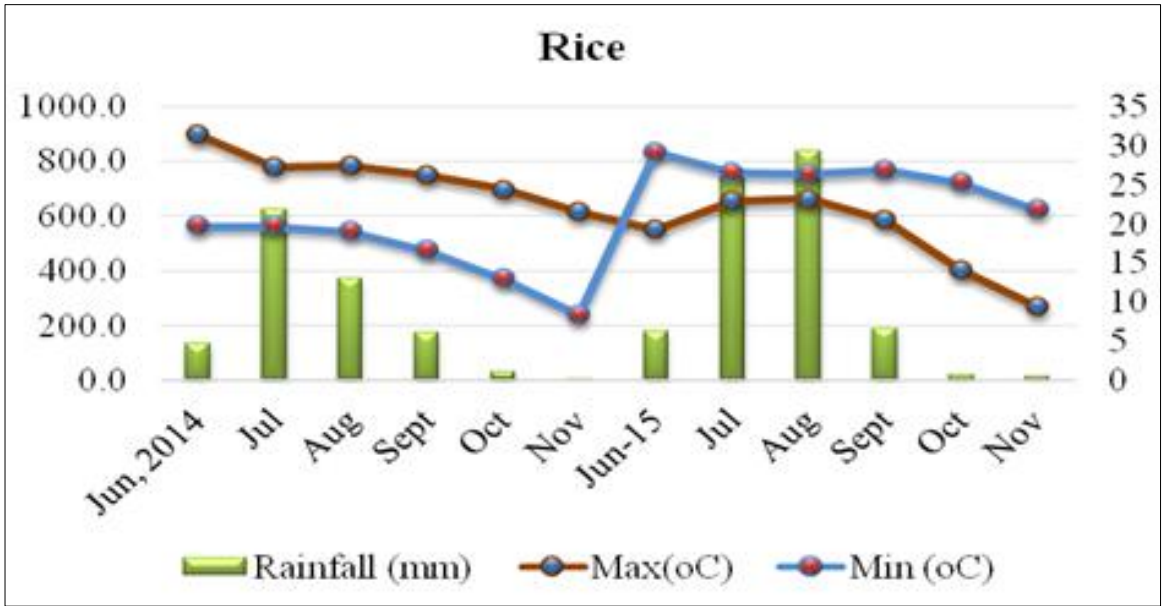

Fig 1. Mean monthly weather data at Palampur (HP) for the period June 2014 and 2015 to November 2014 and 2015; Rainfall, Maximum Temperature and Minimum Temperature

Plant Population (No. /m^2)

Rice tiller number/m^2 reached maximum at 60 DAT and thereafter showed a declining trend till maturity during both years. These results were in conformity with findings of Puli *et al.* (2016) [13]. The treatment effects are described at the maximum population (60 DAT) stage (Table 3). At this stage the tiller number was ranging from 140.6 to 222.8 in 2014 and 132.0 to 224.0 in 2015. All the treatments resulted in significant increase in plant population/m^2 over the control (T_1) during both the cropping season of 2014 and 2015. Consistently highest number of shoots/m^2 were recorded under T_6 where 50% NPK through fertilizers and 50% N through FYM to rice and 100% NPK through fertilizers to wheat were applied followed by T_{11} (75% NPK through fertilizer and 25% N through green manure to rice & 75% NPK to wheat) during both the years. Among different organics, FYM application gave maximum number of tillers over rest of the sources (Puli *et al.* 2016) [13]. Higher radiation interception as well as better nutrition of crop plants due to FYM application, might have increased the photosynthesis rate which was reflected in a significant increase in the number of tillers/m^2 at all the dates of observation (Singh and Mandal 1997) [23]. Tillering is an important trait for grain production and is thereby in rice yield. Mirza *et al.* (2010) [9]

reported increase in number of tillers in rice plants due to influence of different fertilizer combinations. According to them more number of tillers/m^2 might be due to more availability of nitrogen, which plays a vital role in cell division.

Table 3: Effect of treatments on plant population (No. /m^2) and plant height (cm) of rice

Treatment	Plant population (60 DAT)		Plant height (Harvest)	
	2014	2015	2014	2015
T_1 - Control (No nutrients to each crop)	140.6	132.0	76.7	83.9
T_2 - 50% NPK* to each crop	165.0	141.9	77.0	87.7
T_3 - 50% NPK to rice & 100% NPK to wheat	144.7	168.3	74.9	91.8
T_4 - 75% NPK to each crop	154.5	162.9	78.2	85.3
T_5 - 100% NPK to each crop	182.9	165.0	76.4	89.5
T_6 - 50% NPK + 50% N (FYM*) to rice & 100% NPK to wheat	222.8	224.0	79.3	99.6
T_7 - 75% NPK + 25% N (FYM) to rice & 75% NPK to wheat	193.8	175.0	76.5	95.9
T_8 - 50% NPK + 50% N (WCS*) to rice & 100% NPK to wheat	156.3	157.0	76.1	90.3
T_9 - 75% NPK + 25% N (WCS) to rice & 75% NPK to wheat	159.5	160.9	78.0	89.3
T_{10} - 50% NPK + 50% N (GM*) to rice & 100% NPK to wheat	190.8	177.7	75.8	95.0
T_{11} - 75% NPK + 25% N (GM) to rice & 75% NPK to wheat	197.2	181.2	76.7	91.5
T_{12} - Farmers' practice	177.8	169.7	77.3	88.8
LSD (P=0.05)	24.3	27.1	NS	4.6

*NPK- Through fertilizers, FYM- Farmyard manure, WCS- Wheat cut straw, GM- Green manure

Plant Height (cm)

The data on plant height at harvest has also been given in Table 3. A cursory glance at the data revealed that nutrient management treatments did not exhibit any significant effect on plant height of rice at harvest during 2014. However, during 2015, T_6 (50% NPK through fertilizers in combination with 50% N through FYM to rice and 100% NPK through fertilizers to wheat) being at par with T_7 (75% NPK through fertilizer with 25% N through FYM to rice and 75% NPK through fertilizer to wheat) and T_{10} (50% NPK through fertilizer in combination with 50% N through GM to rice and 100% NPK through fertilizer to wheat) resulted in significantly higher plant height of rice at harvest. Azad and Lehria (2001) [2] also recorded increased plant height with the application of FYM. Sharma and Mittra (1988) [18] observed an increase in plant height of rice with the incorporation of dhaincha. Muhammad (2008) [11] observed similar results with application of organic manure and compost in rice. Farmers' practice of fertilizer application (T_{12}) also resulted in significant increase in plant height over the control (T_1). Chemical fertilizers offer nutrients which are readily soluble in soil solution and thereby instantly available to plants. Nutrient availability from organic sources is due to microbial action and improved physical condition of soil (Sarker *et al.* 2004; Puli *et al.* 2016) [16] [13]. The increase in plant height in response to application of organic and chemical fertilizers was probably due to enhanced availability of nutrients (Puli *et al.* 2016a) [12].

Development Stages

The number of days taken for heading was significantly influenced due to different fertility treatments (Table 4). Heading was earliest in T_6 (50% NPK and 50% N (FYM) to rice and 100% NPK to wheat) and was too late in control (T_1) during both the years. The maturity of rice was also significantly affected by fertilizer treatments. Application of NPK significantly hastened the crop maturity during both the years (Table 4). Days taken to maturity were lowest in treatment where 50% NPK was applied through fertilizers and 50% N through FYM to rice and 100% NPK to wheat (T_6). Crop maturity was significantly late under T_1 when no fertilizers and manures were applied. The number of days taken for heading and maturity in rice (Table 4) were hastened in the plots manured with conjoint application of organics [FYM, green manure (dhaincha) and wheat cut straw] and fertilizers in rice as well as succeeding wheat crop due to the direct and residual effect (Mehta 2004) [8]. This is because conjoint application of organics and chemical fertilizers resulted in early boost of vegetative growth due to better nutrition and thus, the attainment of physiological stages was enhanced. These findings are in agreement with Kumar (2001) [6] and Shah *et al.* (2004) [17].

Table 4. Effect of treatments on days taken to flowering and maturity in rice

Treatment	Heading		Maturity	
	2014	2015	2014	2015
T_1 - Control (No nutrients to each crop)	69	69	141	140
T_2 - 50% NPK* to each crop	67	67	135	135
T_3 - 50% NPK to rice & 100% NPK to wheat	64	64	134	133
T_4 - 75% NPK to each crop	64	63	131	129
T_5 - 100% NPK to each crop	63	63	129	128
T_6 - 50% NPK + 50% N (FYM*) to rice & 100% NPK to wheat	59	59	127	125
T_7 - 75% NPK + 25% N (FYM) to rice & 75% NPK to wheat	60	60	131	129
T_8 - 50% NPK + 50% N (WCS*) to rice & 100% NPK to wheat	61	61	129	127
T_9 - 75% NPK + 25% N (WCS) to rice & 75% NPK to wheat	62	62	128	127
T_{10} - 50% NPK + 50% N (GM*) to rice & 100% NPK to wheat	59	59	129	128
T_{11} - 75% NPK + 25% N (GM) to rice & 75% NPK to wheat	65	65	129	128
T_{12} - Farmers' practice	67	67	137	135
LSD (P=0.05)	1.1	0.7	4.4	2.5

*NPK- Through fertilizers, FYM- Farmyard manure, WCS- Wheat cut straw, GM- Green manure

Yield

Transplanting of rice crop during *kharif*, was done on June 28, 2014 and July 18, 2015. The crop (*kharif*) was harvested on October 28, 2014 and November 7, 2015 at maturity when more than 80% of the grains had ripened. Table 5 embodies the data with respect to rice grain and straw yield as influenced by different treatments. Rice grain yield varied from a lowest of 3051 and 3168 kg/ha in the plots where no manures or fertilizers were used (T_1) to a highest of 6529 and 6732 kg/ha in the plots which received 50% NPK through chemical fertilizers and 50% N through FYM to rice and 100% NPK through chemical fertilizer to wheat (T_6) during 2014 and 2015, respectively. Application of chemical fertilizers alone or in combination with organic manures increased the grain yield of rice significantly over control. The higher yield was owed to improved growth and some other factors like development of plant and yield attributes. The plots where farmer practice (T_{12}) was followed, there was increase of 53.3 and 35.5% in grain yield of rice over control during 2014 and 2015, respectively. Among different organic fertilizers FYM and green manure proved superior over wheat cut straw. Substitution of 50% N through any of the organic materials resulted in higher yield as compared to 25% substitution rate, the differences however, were not significant.

Like grain yield, straw yield of rice (Table 5) was also highest (7194 and 7688 kg/ha) under the treatment (T_6) where 50% NPK and 50% N through FYM to rice and 100% NPK through fertilizer to wheat to wheat was applied and the lowest (2410 and 3295 kg/ha) was recorded under control (T_1). Amongst the different sources of organics FYM proved best followed by green manure and wheat cut straw. Beside nutritional effect, application of organic manure help in improvement of soil physical environment like optimum bulk density, particle density, porosity and water holding capacity etc. Favourable soil physical environment stimulate root growth and thus increase the capacity of plants for efficient utilization of nutrients and water resulted in better shoot growth and consequently higher grain yields (Mishra and Sharma, 1997) [10]. Similar findings on the improvement of grain and straw yield of rice with organics have also been reported by Singh *et al.* (2001) [21]; Gupta *et al.* (2006) [5]; Chaudhary and Thakur (2007) [3]; Urkurkar *et al.* (2010) [25]. The FYM addition could be preferred over all other treatments for sustaining higher yields. In absence of FYM, green manure or wheat straw could be an alternative for sustaining higher grain yield of rice and wheat in acidic soils. Use of FYM might have improved the physico-chemical properties of soil that resulted in increased productivity (Singh *et al.* 2017) [22]. Further, the organic matter supplies macro and micronutrients and several other complexing agents, which maintain balanced supply of nutrients to crop. These results are also in conformity with the earlier findings (Sharma *et al.* 2005) [20].

Table 5. Grain and straw yield (kg/ha) of rice as affected by different treatments during 2014 and 2015

Treatment	Grain yield		Straw yield	
	2014	2015	2014	2015
T_1 – Control (No nutrients to each crop)	3051	3168	2410	3295
T_2 – 50% NPK* to each crop	4725	4542	4297	4752
T_3 – 50% NPK to rice & 100% NPK to wheat	5318	5233	5389	5666
T_4 – 75% NPK to each crop	4926	5076	5045	5907
T_5 – 100% NPK to each crop	5152	5229	5888	6017
T_6 – 50% NPK + 50% N (FYM*) to rice & 100% NPK to wheat	6529	6732	7194	7688
T_7 – 75% NPK + 25% N (FYM) to rice & 75% NPK to wheat	5627	5998	6007	6552
T_8 – 50% NPK + 50% N (WCS) to rice & 100% NPK to wheat	4986	5151	3917	5235
T_9 – 75% NPK + 25% N (WCS) to rice & 75% NPK to wheat	4725	4748	5009	5076
T_{10} - 50% NPK + 50% N (GM) to rice & 100% NPK to wheat	6398	5950	5591	6366
T_{11} - 75% NPK + 25% N (GM to rice) & 75% NPK to wheat /	5306	5248	5971	5436
T_{12} - Farmers' practice	4855	4941	5116	5583
LSD (P=0.05)	1024	1060	1521	1495

*NPK- Through fertilizers, FYM- Farmyard manure, WCS- Wheat cut straw, GM- Green manure

Conclusion

This study highlights the impact of INM on growth, development and yield of rice in rice-wheat cropping system. Treatment 6 (T_6) performs better than other treatments which underlines the significance of INM in growth and development of crop. Heading was earliest in T_6 (50% NPK and 50% N (FYM) to rice and 100% NPK to wheat. The maturity of rice was also significantly affected by fertilizer treatments. Application of NPK significantly hastened the crop maturity during both the years. Days taken to maturity were lowest in treatment where 50% NPK was applied through fertilizers and 50% N through FYM to rice and 100% NPK to wheat (T_6). Grain yield, straw yield of rice was highest (7194 and 7688 kg/ha) under the treatment (T_6) where 50% NPK and 50% N through FYM to rice and 100% NPK through fertilizer to wheat to wheat was applied.

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