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Effect of seed pelleting and integrated nutrient management on seed quality of bell pepper (*Capsicum annuum* L.)

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Abstract
The laboratory experiments on effect of seed pelleting and integrated nutrient management on seed quality of seed quality of bell pepper (*capsicum annuum* L.) were conducted for two consecutive years (2016-17 and 2017-18) at Department of Seed Science and Technology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan. The study revealed that seed pelleting and integrated nutrient application during crop growth period influenced the seed quality parameters of resultant seeds. Individually seed pelleting and integrated nutrient management exhibit highly significant effect on all the seed quality attributes like 1000 seed weight, germination, seedling length, seedling dry weight, seed vigour index-L and seed vigour index-M. Interaction effect of seed pelleting and integrated nutrient exhibit significant effect only on seedling length and seedling dry weight.

Keywords: Bell pepper, integrated nutrient management, laboratory, pelleting, seed quality

Introduction
The Bell pepper (*Capsicum annuum* L.) commonly known as sweet pepper, capsicum, green pepper or Shimla mirch, belongs to family Solanaceae. The native of bell pepper is reported to be Meso-America (Mexico and Central America) and South America which is now cultivated all over the world Bosland (1992) [5]. Bell pepper was brought to India by the Portugese from Brazil prior to 1885. It was introduced to Himachal Pradesh by the British in the 19th century. Bell pepper has attained a status of high value crop in India in recent years and occupies a pride of place among vegetables in Indian cuisine because of its delicacy and pleasant flavour coupled with rich content of ascorbic acid, other vitamins and minerals Agarwal *et al.* (2007). Bell pepper is a warm season crop sensitive to low temperatures and frosts. It is cultivated in altitudes that range from sea-level to elevations of 3000 m above mean sea level. The optimal temperature range for pepper is 20 °C to 25 °C). Bell pepper is mainly cultivated in Himachal Pradesh, Uttar Pradesh, parts of Gujarat, Uttarakhand, Jammu and Kashmir, and parts of West Bengal, Maharashtra and Karnataka Chadha (2005) [6]. It has been realized that high quality seed is stepping stone for higher productivity of the crops. Seed is the basic input in agriculture upon which all other inputs rely. The use of improved seed of high quality alone has the capacity to increase the yield up to 40%. The production of healthy bell pepper crop depends on the quality of seed. Therefore it is necessary to focus on the important practices which affect fruit growth and ultimately the seed quality. Among different factors, seed pelleting and integrated nutrient management has the potential to increase the seed quality parameters of the harvested seeds of bell pepper. Seed pelleting improves the chances of successful seedling establishment and integrated nutrient management allows the continuous supply of balanced nutrients throughout the crop growth duration which ultimately contributing to the increased seed yield of high quality. With this background the present investigation entitled effect of seed pelleting and integrated nutrient management on seed quality of bell pepper (*Capsicum annuum* L.)

Material and Methods
The experimental trial was conducted at of Department of laboratory of Seed Science and Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, HP during Kharif seasons of 2016-17 and 2017-18. The present studies comprised of, four pelleting treatments viz. P_0: unpelleted (control), P_1: Zinc sulphate ($ZnSO_4$), P_2: Potassium dihydro

orthophosphate (KH_2PO_4), P_4: Boric acid (H_3BO_3) and six integrated nutrient management treatments viz. N_1: recommended dose of NPK (100:75:55 kg/ha), N_2: *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) + KSB (2.5 kg/ha), N_3: *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) + KSB (2.5 kg/ha) + 90% recommended dose of NPK, N_4: *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) + KSB (2.5 kg/ha) + 80% recommended dose of NPK, N_5: *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) + KSB (2.5 kg/ha) + 70% recommended dose of NPK, N_6: *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) + KSB (2.5 kg/ha) + 60% recommended dose of NPK. In all there were 24 (4x6) different treatment combinations of seed pelleting and integrated nutritional management. The laboratory experiment was in Completely Randomized Design with four replications. Blotter paper method was used for seed quality testing**.** 100 seeds were planted on each blotter paper and kept in germinator at 26 ^{0}C for 14 days. First and final seedling count was taken at 7th and 14th day, respectively. The observation were recorded on 1000 seed weight (g), germination percentage (%), seedling length (cm), seedling dry weight (mg), seed vigour index-Length & Mass and ripe fruit rot incidence (%). Seed vigour-Length and Mass (SVI-I & II) were calculated as per the formula given by Khare and Bhale (2000) [13]. The statistical analysis of recorded observations was done as per design of the experiment as suggested by Gomez and Gomez (1984) [9].

Results and discussion

Main effect of seed pelleting

The pooled analysis of data indicated highly significant differences for the main effect of seed pelleting on seed quality of bell pepper.

The pooled analysis of data presented in Table 1 revealed that maximum 1000 seed weight (5.05 g) was recorded in P_1 (seeds pelleted with zinc sulphate). Increased 1000 seed weight in seeds pelleted with zinc sulphate could be attributed to the efficient metabolism and translocation of carbohydrate from source (leaf) to sink (seed) and bigger, good quality fruits resulting in bold seeds, which ultimately increases the seed weight. The results of the present findings are in conformity with the findings of Aruna kumar *et al*. (2013) [3] who recorded higher 1000 seed weight in seeds pelleted with zinc sulphate in sesame. Similar results was also recorded by Manjunath *et al*. (2009) [14] in paprika chilli.

The pooled analysis of data presented in Table 2 revealed that maximum germination (90.75%) was recorded in P_1 (seed pelleted with zinc sulphate). The seeds pelleted with zinc sulphate produced maximum germination, because of the fact that zinc element is involved in auxin metabolism and plays a vital role in seed set, seed development and quality. Higher seed germination was noticed in the present study may be due to well-developed seeds with higher test weight and higher dehydrogenase enzyme activity. Hence, direct availability of zinc sulphate to the mother plant led to the production of good quality seed. The present results are in conformity with the findings of Manjunath *et al.* (2009) [14] who recorded maximum seed germination of harvested seed from zinc sulphate pelleted seeds in paprika chilli. Similar results were also recorded by Rathinavel *et al*. (2000) [18] in cotton.

The pooled analysis of data presented in Table 3 revealed that maximum seedling length (8.19 cm) was recorded in P_1 (seed pelleted with zinc sulphate). Seeds pelleted with zinc sulphate produced maximum seedling length of harvested seed probably due to enhanced metabolic activity, earliness in germination and seedling growth. Such beneficial effect on seedling growth was reported by Jagathambal (1996) [10] in sorghum. The result of the present study are in accordance with the findings of the Dileepkumar *et al.* (2009) [7] who recorded maximum seedling length of harvested seed in seeds pelleted with zinc sulphate in cowpea.

The pooled analysis of data presented in Table 4 revealed that maximum seedling dry weight (2.61 mg) was recorded in P_1 (seed pelleted with zinc sulphate). Highest seedling dry weight of harvested seeds in seed pelleting with zinc sulphate, may be because of the fact that higher 1000 seed weight was recorded in the same treatment i.e. seeds pelleted with the zinc sulphate this gives an indication that the seeds had higher reserve food material which led to the increased seedling dry weight. The results of the present study are in line with the findings of the Dileepkumar *et al*. (2009) [7] who recorded maximum seedling dry weight in cowpea with zinc sulphate pelleted seeds. Shashibaskar *et al*. (2011) [20] also concluded that zinc sulphate pelleted seeds produce highest seedling dry weight in tomato. Similar results were also produced by Menaka and Vanangamudi (2008) [15] in bajra and Manjunath *et al.* (2009) [14] in paprika.

The pooled analysis of data presented in Table 5 revealed that maximum seed vigour index-Length (744.83) was recorded in P_1 (seeds pelleted with zinc sulphate). Enhanced seed vigour index-Length of harvested seeds was recorded in seeds pelleted with zinc sulphate which may be due to proper mother plant nourishment which in turn may enhance the seed quality and vigour having more germination and seedling length. Results of the present study are in conformity with the finding of the Dileepkumar *et al*. (2009) [7] who recorded maximum seed vigour index in cowpea with zinc sulphate pelleted seeds. Similar results were also recorded by Rathinavel *et al.* (2000) [18] in cotton.

The pooled analysis of data presented in Table 6 revealed that maximum seed vigour index-Mass (238.21) was recorded in P_1 (seed pelleted with zinc sulphate). Increased seed vigour index-Mass of harvested seeds in seeds pelleted with zinc sulphate may be due to proper mother plant nourishment which in turn may enhance the seedling vigour in terms of higher germination and seedling dry weight. The results of the present study are in accordance with the findings of the Shashibhaskar *et al*. (2011) [20] who recorded maximum seedling vigour index with zinc sulphate pelleted seeds in tomato. Dileepkumar *et al.* (2009) [7] also concluded that zinc sulphate pelleting in cowpea produced highest seedling vigour index in cowpea. Similar results were also recorded by Vasudevan *et al*. (1997) [22] in sunflower and Manjunath *et al.* (2009) [14] in paprika chilli.

Main effect of integrated nutrient management

The pooled analysis of data indicated highly significant differences for the main effect of integrated nutrient management on seed quality of bell pepper.

The pooled analysis of data presented in Table 1 revealed that maximum 1000 seed weight (5.11 g) was recorded in N_4 (application of *Azotobacter* +PSB + KSB + 80% recommended dose of NPK). Increase in thousand seed weight with the application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK may be due to increased availability of essential nutrients in the presence biofertilizers. Results of the present study are in accordance with the findings of the Kumar and Sharma (2006) [12], Geetharani and Parthiban (2014) [8] and Angadi *et al*. (2017) [2].

The pooled analysis of data presented in Table 2 revealed that maximum germination (91.66%) was recorded in N_4 (soil application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK). In the present study, maximum germination of harvested seeds in N_4, may be due to optimum availability of nutrients at all stages of plant growth and thus gave bold, good quality and vigorous seeds. Further, increase in seed germination may be due to improved quality of seed in terms of crude proteins, nitrogen and mineral content in seeds because availability of desired quantity of NPK through organic and inorganic fertilizers. The present results are in line with the findings of the Vasisht *et al.* (1979) [21] in okra. Improved seed germination by application of PSB has also been reported by Sharma *et al*. (2007) [19] in *Cicer arietinum*.

The pooled analysis of data presented in Table 3 revealed that maximum seedling length (8.30 cm) was recorded in N_4 (soil application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK). Maximum seedling length was in N_4 may be for the reason that bolder seeds were produced in the same treatment i.e N_4 which have sufficient food reserves, resulting into better seedling growth. The present results are in close agreement with the findings of Angadi *et al*. (2017) [2] in tomato. Similar results were also reported by Geetharani and Parthiban (2014) [8] in tomato.

The pooled analysis of data presented in Table 4 revealed that maximum seedling dry weight (2.63 mg) was recorded in N_4 (application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK). Application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK produced maximum seedling dry weight of harvested seeds, which may be due to optimum availability of nutrients at all stages of plant growth and thus gave bold, good quality and vigorous seeds resulting in higher dry matter accumulation. The results of the present study are in accordance with the findings of Rahman *et al.* (1996) [17] and Angadi *et al*. (2017) [2] in tomato.

The pooled analysis of data presented in Table 5 revealed that maximum seedling vigour index-Length (761.30) was recorded in N_4 (application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK). Application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK produced maximum seedling vigour index-Length of harvested seeds which may be due to the fact that biofertilizers may have helped the availability of various nutrients at optimum level. Application of inorganic fertilizers on the other hand may have helped the plant metabolism by supplying nutrients in early growth phase which might produce highly vigorous seeds. The results of the present study are in line with the findings of Rahman *et al*. (1996) [17] in tomato and Birwa *et al*. (2009) [4] in okra. Karibasappa *et al*. (2007) [11] were also of the opinion that improvement in all seed quality parameters including seed vigour index of plant could be attributed to higher assimilatory surface which was due to photosynthetic activity and genetic makeup of the crop.

The pooled analysis of data presented in Table 6 revealed that maximum seedling vigour index-Mass (242.01) was recorded in N_4 (soil application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK). Application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK produced maximum seed vigour index-Mass of harvested seeds which may be due to adequate availability of nutrients in the desired quantity that may have helped the plants producing high vigorous seeds. The present results are in line with the findings of the Rahman *et al.* (1996) [17] in tomato and Panwar *et al.* (2000) [16] in radish.

The interaction between pelleting and integrated nutrient management

The pooled analysis of data revealed that among interactions between seed pelleting and integrated nutrient management revealed that maximum seedling length (8.84 cm) and maximum seedling dry weight (2.99 mg) was recorded in treatment combination P_1N_4 (seed pelleted with zinc sulphate + application of *Azotobacter* + PSB + KSB + 80% recommended dose of NPK). However the interaction between seed pelleting and integrated nutrient management (P x N) was found to be non-significant for 1000 seed weight, germination%, seedling vigour index-Length and seedling vigour index-Mass.

Table 1: Effect of seed pelleting and integrated nutrient management on 1000 seed weight (g) of seed crop of bell pepper cv. Solan Bharpur. Pooled mean (2016 and 2017)

Particulars	1000 seed weight (g)						
	Integrated nutrient management						
Pelleting	N_1	N_2	N_3	N_4	N_5	N_6	Mean
P_0	4.73	4.63	4.93	5.03	4.86	4.72	4.82
P_1	5.02	4.92	5.14	5.26	5.11	4.88	5.05
P_2	4.93	4.80	5.04	5.10	5.00	4.84	4.95
P_3	4.87	4.73	5.01	5.07	4.97	4.80	4.91
Mean	4.89	4.77	5.03	5.11	4.98	4.81	
$CD_{(0.05)}$							
P	0.06						
N	0.07						
PxN	NS						

P -Seed pelleting treatments
N- Integrated nutrient management
P_0 - Control (unpelleted), P_1 - Zinc sulphate ($ZnSO_4$), P_2 - Potassium dihydro orthophosphate (KH_2PO_4), P_4 - Boric acid (H_3BO_3).
N_1- Recommended dose of NPK (100:75:55 kg/ha, N_2- *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) +KSB (2.5 kg/ha), N_3- *Azotobacter* + PSB +KSB+ 90% Recommended dose of NPK, N_4 - *Azotobacter* + PSB +KSB+80% Recommended dose of NPK, N_5 - *Azotobacter* + PSB +KSB+70% Recommended dose of NPK, N_6 - *Azotobacter* + PSB +KSB+ 60% Recommended dose of NPK

Table 2: Effect of seed pelleting and integrated nutrient management on germination (%) of harvested seed of bell pepper cv. Solan Bharpur. Pooled mean (2016 and 2017)

Particulars	Germination (%)						
	Integrated nutrient management						
Pelleting	N_1	N_2	N_3	N_4	N_5	N_6	Mean
P_0	90.16 (71.71)	83.00 (65.62)	90.50 (72.07)	91.00 (72.60)	90.16 (71.72)	87.50 (69.29)	88.72 (70.50)
P_1	91.00 (72.60)	87.50 (69.29)	91.83 (73.44)	92.83 (74.45)	91.50 (73.05)	89.83 (71.41)	90.75 (72.37)
P_2	90.50 (72.05)	85.50 (67.60)	90.83 (72.39)	91.66 (73.21)	90.66 (72.20)	89.00 (70.60)	89.69 (71.34)
P_3	90.50 (72.06)	84.66 (66.92)	90.83 (72.35)	91.16 (72.70)	90.50 (72.06)	88.33 (70.02)	89.33 (71.02)
Mean	90.54 (72.11)	85.16 (67.36)	91.00 (72.56)	91.66 (73.24)	90.70 (72.26)	88.66 (70.33)	
$CD_{(0.05)}$							
P	0.97						
N	1.19						
PxN	NS						

P -Seed pelleting treatments
N- Integrated nutrient management
P_0 - Control (unpelleted), P_1 - Zinc sulphate ($ZnSO_4$), P_2 - Potassium dihydro orthophosphate (KH_2PO_4), P_4 - Boric acid (H_3BO_3).
N_1- Recommended dose of NPK (100:75:55 kg/ha, N_2- *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) +KSB (2.5 kg/ha), N_3- *Azotobacter* + PSB +KSB+ 90% Recommended dose of NPK, N_4 - *Azotobacter* + PSB +KSB+80% Recommended dose of NPK, N_5 - *Azotobacter* + PSB +KSB+70% Recommended dose of NPK, N_6 - *Azotobacter* + PSB +KSB+ 60% Recommended dose of NPK

Table 3: Effect of seed pelleting and integrated nutrient management on Seedling length (cm) of harvested seed of bell pepper cv. Solan Bharpur. Pooled mean (2016 and 2017)

Particulars	Seedling length (cm)						
	Integrated nutrient management						
Pelleting	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**	**N_6**	**Mean**
P_0	7.13	6.07	7.30	7.35	7.27	7.04	7.02
P_1	8.05	7.03	8.70	8.84	8.56	7.97	8.19
P_2	7.85	6.76	8.41	8.57	8.33	7.75	7.94
P_3	7.73	6.50	8.39	8.44	8.15	7.66	7.81
Mean	7.69	6.59	8.20	8.30	8.08	7.60	
$CD_{(0.05)}$							
P	0.07						
N	0.08						
PxN	0.16						

P -Seed pelleting treatments
N- Integrated nutrient management
P_0 - Control (unpelleted), P_1 - Zinc sulphate ($ZnSO_4$), P_2 - Potassium dihydro orthophosphate (KH_2PO_4), P_4 - Boric acid (H_3BO_3).
N_1- Recommended dose of NPK (100:75:55 kg/ha, N_2- *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) +KSB (2.5 kg/ha), N_3- *Azotobacter* + PSB +KSB+ 90% Recommended dose of NPK, N_4 - *Azotobacter* + PSB +KSB+80% Recommended dose of NPK, N_5 - *Azotobacter* + PSB +KSB+70% Recommended dose of NPK, N_6 - *Azotobacter* + PSB +KSB+ 60% Recommended dose of NPK

Table 4: Effect of seed pelleting and integrated nutrient management on seedling dry weight (mg) of harvest seed of bell pepper cv. Solan Bharpur. Pooled mean (2016 and 2017)

Particulars	Seedling dry weight (mg)						
	Integrated nutrient management						
Pelleting	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**	**N_6**	**Mean**
P_0	2.12	1.94	2.25	2.33	2.19	2.06	2.15
P_1	2.58	2.19	2.87	2.99	2.67	2.40	2.61
P_2	2.34	2.06	2.52	2.68	2.45	2.27	2.38
P_3	2.31	1.98	2.41	2.55	2.33	2.21	2.30
Mean	2.34	2.04	2.51	2.63	2.41	2.23	
$CD_{(0.05)}$							
P	0.05						
N	0.07						
PxN	0.13						

P -Seed pelleting treatments
N- Integrated nutrient management
P_0 - Control (unpelleted), P_1 - Zinc sulphate ($ZnSO_4$), P_2 - Potassium dihydro orthophosphate (KH_2PO_4), P_4 - Boric acid (H_3BO_3).
N_1- Recommended dose of NPK (100:75:55 kg/ha, N_2- *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) +KSB (2.5 kg/ha), N_3- *Azotobacter* + PSB +KSB+ 90% Recommended dose of NPK, N_4 - *Azotobacter* + PSB +KSB+80% Recommended dose of NPK, N_5 - *Azotobacter* + PSB +KSB+70% Recommended dose of NPK, N_6 - *Azotobacter* + PSB +KSB+ 60% Recommended dose of NPK

Table 5: Effect of seed pelleting and integrated nutrient management on seedling vigour index-Length of harvested seed of bell pepper cv. Solan Bharpur. Pooled mean (2016 and 2017)

Particulars	Seedling vigour index-Length						
	Integrated nutrient management						
Pelleting	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**	**N_6**	**Mean**
P_0	642.92	504.28	660.68	668.90	656.04	616.55	624.90
P_1	732.76	615.69	799.12	821.13	783.79	716.49	744.83
P_2	710.53	578.53	764.54	785.69	755.40	689.78	714.08
P_3	700.13	550.40	762.10	769.46	737.70	677.19	699.49
Mean	696.59	562.23	746.61	761.30	733.23	675.00	
$CD_{(0.05)}$							
P	13.43						
N	16.45						
PxN	NS						

P -Seed pelleting treatments
N- Integrated nutrient management
P_0 - Control (unpelleted), P_1 - Zinc sulphate ($ZnSO_4$), P_2 - Potassium dihydro orthophosphate (KH_2PO_4), P_4 - Boric acid (H_3BO_3).
N_1- Recommended dose of NPK (100:75:55 kg/ha, N_2- *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) +KSB (2.5 kg/ha), N_3- *Azotobacter* + PSB +KSB+ 90% Recommended dose of NPK, N_4 - *Azotobacter* + PSB +KSB+80% Recommended dose of NPK, N_5 - *Azotobacter* + PSB +KSB+70% Recommended dose of NPK, N_6 - *Azotobacter* + PSB +KSB+ 60% Recommended dose of NPK

Table 6: Effect of seed pelleting and integrated nutrient management on seedling vigour index-Mass of harvested seed of bell pepper cv. Solan Bharpur. Pooled mean (2016 and 2017)

Particulars	Seedling vigour index-Mass						
	Integrated nutrient management						
Pelleting	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**	**N_6**	**Mean**
P_0	191.64	161.47	203.69	212.16	197.95	180.32	191.20
P_1	235.32	192.18	263.63	277.58	244.40	216.12	238.21
P_2	212.31	176.25	229.47	245.75	222.23	202.05	214.68
P_3	209.57	168.12	219.40	232.55	211.36	195.67	206.11
Mean	212.21	174.50	229.05	242.01	218.99	198.54	
$CD_{(0.05)}$							
P	7.12						
N	8.72						
PxN	NS						

P -Seed pelleting treatments
N- Integrated nutrient management
P_0 - Control (unpelleted), P_1 - Zinc sulphate ($ZnSO_4$), P_2 - Potassium dihydro orthophosphate (KH_2PO_4), P_4 - Boric acid (H_3BO_3).
N_1- Recommended dose of NPK (100:75:55 kg/ha, N_2- *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) +KSB (2.5 kg/ha), N_3- *Azotobacter* + PSB +KSB+ 90% Recommended dose of NPK, N_4 - *Azotobacter* + PSB +KSB+80% Recommended dose of NPK, N_5 - *Azotobacter* + PSB +KSB+70% Recommended dose of NPK, N_6 - *Azotobacter* + PSB +KSB+ 60% Recommended dose of NPK

Conclusions

The present study revealed that use of seeds pelleted with P_1N_4 (zinc sulphate + application of *Azotobacter* (2.5 kg/ha) + PSB (2.5 kg/ha) + KSB (2.5 kg/ha) + 80% recommended dose of NPK) influenced the seed quality attributes of bell pepper and the treatment P_1N_4 appears to be a suitable combination for high seed quality of bell pepper in sub-temperate climate of Himachal Pradesh, India.

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