



International Journal of
**Agricultural
Research**

ISSN 1816-4897



Academic
Journals Inc.

www.academicjournals.com

Influence of NPK Fertilization on Productivity and Oil Yield of Groundnut (*Arachis hypogaea*) and Sunflower (*Helianthus annuus*) in Intercropping System under Irrigated Condition

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Abstract: A field experiment has been conducted at garden lands (*Vertic ustochrept*) of Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during Kharif (June to October) season of 2004 to ascertain the optimum nutrient requirement for groundnut+sunflower intercropping system under irrigated conditions with replacement series to enhance the productivity of groundnut+sunflower inter cropping system. Groundnut was raised as main crop and sunflower was planted as intercrop with 3:1 ratio. There were ten treatments viz., control (T₁), 100% Recommended Dose of Fertilizers (RDF) to main and inter crops (T₂), 100% RDF to main crop+no fertilizer to intercrop (T₃), 100% RDF to main crop+100% RDF to intercrop (T₄), 100% RDF to main crop+50% RDF of intercrop (T₅), T₃+50% RDF to intercrop as basal+50% N to intercrop as top dress (T₆), T₃+50% N to intercrop as basal (T₇), T₃+100% PK of intercrop as basal+50% N as basal+50% N as top dress (T₈), pure crop of sunflower with RDF (T₉) and pure crop of groundnut with RDF (T₁₀) were tested in randomized block design with three replications. All the above fertilizer treatments were imposed based on the area. 100% RDF to groundnut (main crop)+100% RDF P and K to sunflower (intercrop)+50% of N basal and 50% of N as top dressing to sunflower increased yield attributes, yield and oil contents of groundnut and sunflower. So, 100% recommended doses of NPK fertilizer to groundnut+100% RDF PK to sunflower with 50% N as basal and 50% (T₈) as top dressing will be optimum to realize maximum yield under groundnut+sunflower intercropping system in irrigated conditions.

Key words: Groundnut, sunflower, intercropping system, NPK fertilization, yield, oil content

INTRODUCTION

In recent days there is mounting interest in diversified agricultural production systems to obtain improved crop protection, increased productivity and profitability offered by many intercropping system. This may be due to some of the established and speculated advantages for intercropping systems such as higher yields, greater land-use efficiency and improvement of soil fertility through the addition of N by fixation and excretion from the component legume (Willey, 1979; Ofori and Stern, 1987). Groundnut (*Arachis hypogaea* L.) is traditionally intercropped with crops like pearl millet, maize and sorghum and also with pigeon pea in groundnut-growing areas of India by marginal and sub-marginal farmers during rainy season (Reddy *et al.*, 1980). Such legume/non-legume mixtures probably reduce competition for nitrogen (N), since the legume depends mainly on its own N fixation while the cereal uses mineral N (Ofori and Stern, 1987; Rerkasem *et al.*, 1988). Many studies of

cereal/legume intercropping have shown that the quantity of N fixed by the legume depends on such factors as the morphology, density and competitive ability of the legume (Ofori and Stern, 1987), the effectiveness of the *rhizobia* symbiosis and the system of intercropping (Rerkasem and Rerkasem, 1988).

Groundnut and sunflower intercropping system is instrumental to maximize the oilseed production per unit area and time. Sunflower-groundnut intercropping boosts the total productivity (Giri and Blaize, 1994). Furthermore, groundnut and sunflower are considered to be the most important oil seed crops of the world due to its wide range adaptability and highest oilseed contents (40-50%). Agroclimatic conditions of India are highly suitable for these crops and can be grown twice a year successfully under irrigated conditions (Reddy *et al.*, 1980). Thus, the efforts have been made to increase the area and production of these crops in the country. Accurately quantifying the optimum fertilizer rate is essential to maximize profitability and minimize potential environmental impact (Chaudhry and Sarwar, 1999). Enough information of nutrient management under intercropping system has not been generated for adoption. This situation warrants the need to find appropriate nutrient management practices in groundnut based intercropping system. The most important factor affecting the growth and yield of oil seeds is mineral nutrition especially nitrogen, phosphorus and potassium. However, nutrient management in intercropping system is more complex than the recommendation for individual crops in a system often proves uneconomical. Therefore, in this approach, the crops that respond most in the intercropping system should only be fertilized and allow the component crops to make use of the applied fertilizers.

The study was conducted with the objectives to study the effect of different fertilizer doses on yield and yield components of sunflower and identify optimum NPK level for maximum productivity under groundnut+sunflower intercropping systems.

MATERIALS AND METHODS

Experimental Site and Initial Soil Characteristics

A field experiment was conducted at garden lands, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during Kharif (June to October) season of 2004-2005 to ascertain the possible nitrogen, phosphorus and potassium management practices to enhance the productivity to groundnut+sunflower intercropping system. The farm is situated in western agro-climatic zone of Tamil Nadu at 11° North latitude and 77° East longitudes at an elevation of 426.7 m above the mean sea level. Soil of the experimental site was well drained sandy loam texture (17.26% clay, 26.13% silt, 43.30% fine sand, 12.31% coarse sand) with low availability of nitrogen, medium in available phosphorus and high in available potassium. The soil analysed 195.00, 12.20 and 380.00 kg ha⁻¹ of KMnO₄-N, Olsen-P and NH₄OAc-K, respectively with bulk density of 1.40 g cm⁻³, EC of 0.42 ds m⁻¹, field capacity 21% and pH of 8.00.

Selection of Cultivar, Experimental Design and Sowing

Based on screening experiment (data not shown) promising performance under intercropping situation and fertilizer response, cultivars of groundnut CO₃ (mutant from POL-1) and sunflower Morden (selection from cerianka) were selected for this study. The variety of groundnut CO₃ is characterized by bunch type, high oil content with low incidence of bud necrosis. Sunflower variety Morden is characterized by short duration, highly compactable in intercropping situation.

Experiment was conducted in Randomized Block Design (RBD) with three replication and ten treatments. The gross plot and net plot size adopted was 23.04 m² (4.8×4.8 m) and 12.96 m² (3.6×3.6 m). The main crop of groundnut was sown on either side of ridges and the intercrop sunflower was sown after every three rows of groundnut. Sowing of groundnut+sunflower at 3:1 ratio was

adopted with replacement series. The groundnut and sunflower seeds were dibbled at the rate of two seeds per hill. Inter row spacing of groundnut and sunflower with 30 and 90 cm, respectively and intra row spacing of groundnut and sunflower with 10 and 30 cm, respectively were adopted.

Fertilizer Schedule

The recommended fertilizer dose of 17:34:54 kg NPK per ha for groundnut and 40:20:20 kg NPK per ha for sunflower was applied as per the treatment schedule. Fertilizers were applied in the form of Urea (46% N), Super phosphate (16% P₂O₅) and Muriate of potash (60% K₂O) for both the crop.

Treatment Details

The treatments were imposed as per the treatment schedule. Fertilizer requirement to intercropping system was calculated on area basis. The treatment details are given below:

- T₁ : No fertilizer application
- T₂ : 100 % recommended dose of fertilizers (RDF) to main and inter crop
- T₃ : 100% RDF to main crop+no fertilizer to intercrop
- T₄ : 100% RDF to main crop+100% RDF to intercrop
- T₅ : 100% RDF to main crop+50% RDF of intercrop
- T₆ : T₃+50% RDF to intercrop as basal+50% N to intercrop as top dress
- T₇ : T₃+50% N to intercrop as basal
- T₈ : T₃+100% PK of intercrop as basal+50% N as basal+50% N as top dress
- T₉ : Pure crop of sunflower with RDF
- T₁₀ : Pure crop of groundnut with RDF

Yield Attributes of Groundnut

Shelling Percentage

Randomly selected five hundred pods from each treatment were shelled and percentage of kernel weight to pod weight was determined from each treatment to arrive at shelling percentage.

$$\text{Shelling percentage} = \frac{\text{Kernel weight}}{\text{Pod weight}} \times 100$$

Hundred Kernel Weight

Weight of hundred kernels was recorded for each treatment and expressed in g.

Pod Yield

Pod yield from each of net plot area was recorded after thorough drying and expressed in kg ha⁻¹.

Oil Content

Oil content of sunflower seeds was estimated with the Nuclear Magnetic Resonance (NMR) instrument and expressed in percentage.

Oil Yield

Oil yield was worked out by multiplying the oil content with seed yield and expressed in kg ha⁻¹.

Yield Attributes of Sunflower

Head Diameter

The diameter of the capitulum was measured and expressed in cm.

Hundred Seed Weight

Weight of hundred seeds was recorded for each treatment and expressed in g.

Seed Yield

Seed yield from each plot area was recorded at 14% moisture level and computed to yield per ha and expressed in kg ha⁻¹.

Oil Content

Oil content of sunflower seeds was estimated with the Nuclear Magnetic Resonance (NMR) instrument and expressed in percentage.

Oil Yield

Oil yield was worked out by multiplying the oil content with seed yield and expressed in kg ha⁻¹.

Analysis of Intercropping System

Land Equivalent Ratio (LER)

Land equivalent ratio was calculated as per the procedure given by Mandal *et al.* (1987). LER is the relative land area under sole crops that is required to produce the yields achieved in intercropping system.

Crop Equivalent Yield (CEY)

The yield of intercrop is converted into equivalent yield of any one crop based on the price of the produce. The crop equivalent yield was calculated as follows:

$$CEY = \sum_{i=1}^n (y_i e_i)$$

where, y_i is the yield of i th component, e_i is the equivalent factor of the i th component.

Statistical Analysis

The data from the experiment were analyzed statistically following the procedure given by Gomez and Gomez (1984). Whenever the treatmental differences were significant, critical difference were calculated at five percent probability level and used for interpretations.

RESULTS AND DISCUSSION

Results of shelling percentage, hundred kernel weight, pod yield, head diameter, seed yield, oil content and oil yield of groundnut and sunflower, intercropping system analysis of crop equivalent yield and land equivalent ratio are discussed below.

Groundnut

Yield and Yield Components of Groundnut

Shelling Percentage

Shelling percentage obtained from groundnut under intercropping situation ranged from 64.3 to 70.8% and the maximum shelling percentage was recorded in treatment of 100% RDF to main crop+100% PK of intercrop as basal+50% N as basal+50% N as top dressing(T_8) than other treatments (Table 1). This might be due to the availability of additional nutrients for the effective pod filling. This was in conformity with the finding of Ghosh (2004).

Table 1: Effect on nutrient management practices on shelling percentage, 100-kernal weight (g), Pod yield (kg ha⁻¹), oil content (%) and oil yield (kg ha⁻¹) in groundnut

Treatments	Shelling (%)	100 kernal weight (g)	Pod yield (kg ha ⁻¹)	Oil content (%)	Oilyield (kg ha ⁻¹)
T ₁ -No Fertilizer	64.3	35.5	960	51.2	368
T ₂ -RDF to GN+RDF to SF	70.4	39.2	1392	52.3	552
T ₃ -RDF to GN+No RDF to SF	70.0	38.1	1366	51.2	517
T ₄ -RDF to GN to entire systems	69.7	36.2	1237	51.6	463
T ₅ -T ₃ +50% RDF to SF	70.1	36.3	1295	51.3	524
T ₆ -T ₃ +50% RDF to SF+50% N top	70.2	38.6	1384	51.9	542
T ₇ -T ₃ +50% N to SF basal	69.8	38.2	1340	52.2	512
T ₈ -T ₃ +100% PK+50% N to SF basal+50% N top	70.8	39.9	1465	52.5	584
T ₁₀ -Sole Groundnut	70.2	40.2	1922	52.0	706
SE _d	2.29	1.77	79.27	1.81	18.64
CD (p = 0.05)	NS	NS	168.05	NS	39.52

T₉: Sole crop of sunflower with RDF (Not included for statistical analysis), RDF: Recommended dose of fertilizer, GN: Groundnut; SF: Sunflower, NS: Non significant

Hundred Kernel Weight

Fertilizer application might have increased the amount of available nutrients, which encouraged the production of more number of flowers, gynophores and matured pods. The results of groundnut+sunflower intercropping system showed that higher numbers of matured pods was registered under pure stand (Table 1). Similar observations were reported by Blaize and Giri (1994), who found that the yield attributes except 100-kernel weight of groundnut were significantly reduced in intercropping system against sole crop. This might be attributed to the competition for available nutrients under inter cropping situation. This is accordance with Ghosh (2004).

Pod Yield of Groundnut

In intercropping situation, application of recommended dose of fertilizer to groundnut and two splits application of N with basal application of P and K to the sunflower individually according their area basis produced higher pod yield of 1465 kg ha⁻¹(Table 1). This might be due to higher level of NPK application to intercropping system than the conventional method of fertilizer application. Similar results were reported by AICRP (2002) and Ghosh (2004).

The reproductive sink size and its relative strength appear to have an innate bearing on photosynthesis and consequently the pod yield. Duncan *et al.* (1978) observed partitioning of photosynthate to pods as the most influential physiological factor in yield determination. It is apparent from the results that tall-growing sunflower intercrops significantly affected nitrogen fixation traits in groundnut. Reduced light due to shading by tall-growing cereals may be the cause of poor nodulation in groundnut. This reduced light energy affects N₂-fixation by restricting photosynthesis and the energy supply to roots, thereby reducing nodulation and nodule size (Nambiar *et al.*, 1983). Low N content of groundnut shoots measured in the cereal intercropping systems could be attributed mainly to lower nitrogen fixation and reduced N uptake from soil under restricted photosynthesis. Nambiar *et al.* (1983) observed that when lateral leaves of the sorghum crop were removed, the intercropped groundnut nodulated better and fixed more N. Similar reduction in N₂-fixation of soybean by shading caused by maize was reported by Wahue and Miller (1978). Non-significant differences in the nodulation in the initial stage could be attributed to shorter height of intercrops, which apparently did not create effective shading. Further, maximum nodulation and nitrogen fixation in groundnut are known to occur at the pod filling stage (Nambiar *et al.*, 1986). Thus any discrepancy in nodulation and nitrogen fixation is bound to contribute to differences in pod yield. Hence it is clear that pod yield of groundnut was significantly affected in the intercropping system with sunflower.

The pod yield obtained from the intercropped groundnut was lesser than the pod yield produced under pure stand situation. This might be due to reduction of 33% of population under replacement

series of intercropping situation. This was in accordance with the finding of Blaize and Gajendra Giri (1994) that yields attributes except 100-kernel weight were significantly reduced in intercropping system. Jat and Ahlawat (2004) also emphasized that the better performance of sole crop of groundnut could be attributed to more pods/plant resulting from higher dry matter production. Assimilation and distribution of photosynthates were mainly responsible for better yields of groundnut in sole cropping.

Quality Parameters

Oil Content and Oil Yield

The oil content of groundnut is being genetically controlled one, but it can be modified through better agronomic management practices to certain level of significance.

Potassium was reported to play main role on the oil content of groundnut (Charkaravarthy *et al.*, 2002). Jain *et al.* (1990) also reported that potassium applied during pod development stage increased the oil content in groundnut. The split application of nitrogen (T_3) was found to record higher seed yield and oil content in groundnut+sunflower intercropping system grown under irrigated condition (Table 1). In intercropping system, higher oil content was realized under application of recommended dose of fertilizer to groundnut with split application of nitrogen to sunflower. But there was no significant difference in oil content of groundnut because of different nutrient management practices to component crop of sunflower. The oil content recorded under intercropped groundnut ranged from 51.2 to 52.3%. This is higher than oil content obtained under pure stand. Ghosh (2004) also observed the same in groundnut based intercropping.

Oil yield recorded under intercropping system with the application of recommended dose of fertilizer to groundnut and sunflower produced higher oil yield. The increased oil yield might be attributed to application of fertilizer to both main and component crops (Ghosh, 2004). Application of nutrients only to main crop and reduction of nutrients to intercrop causes nutrient imbalance leading to lower production in oil content.

Sunflower

Yield and Yield Components of Sunflower

Head Diameter

Nutrient management practices in intercropping system had pronounced significant effect on the head diameter of sunflower. Split application of recommended dose of N with basal application of P and K recorded maximum head diameter (Table 2). This might due to the competition for available nutrients for intercropping system. This result was in accordance with the findings of Avilkumar and Reddy (1996). They concluded that the head diameter of sunflower increased with higher levels of

Table 2: Effect on nutrient management practices on Head diameter (cm) Seed yield (kg ha^{-1}), 100 seed weight (g), oil content (%) and oil yield (kg ha^{-1}) in Kharif sunflower

Treatments	Head diameter (cm)	Seed yield (kg ha^{-1})	100 seed weight (g)	Oil content (%)	Oil yield (kg ha^{-1})
T ₁ -No Fertilizer	9.70	356	3.50	27.5	96.40
T ₂ -RDF to GN+RDF to SF	13.90	496	3.90	28.5	168.30
T ₃ -RDF to GN+No RDF to SF	12.80	405	3.60	27.9	107.80
T ₄ -RDF to GN to entire systems	13.00	449	3.90	28.2	154.30
T ₅ -T ₃ +50% RDF to SF	13.30	405	3.70	28.4	123.20
T ₆ -T ₃ +50% RDF to SF+50% N top	13.60	411	3.80	28.3	146.70
T ₇ -T ₃ +50% N to SF basal	12.60	388	3.60	28.1	111.80
T ₈ -T ₃ +100% PK+50% N to SF basal+50% N top	14.10	568	4.10	28.8	172.50
T ₉ -Sole Sunflower	14.60	1372	3.70	30.4	395.70
SE _d	0.48	24.63	0.13	2.09	6.47
CD (p = 0.05)	1.08	52.21	NS	NS	13.60

T₁₀: Sole crop of groundnut with RDF (Not included for statistical analysis), RDF: Recommended dose of fertilizer, GN: Groundnut; SF: Sunflower, NS: Non significant

nitrogen, phosphorus and potassium to intercropping system. The study also confirms the findings of Blaize and Gajendra Giri (1994) that all ratio of groundnut as intercrop suppressed the yield of sunflower against sole crop. P application increases yield and yield components such as head diameter. These results are tally to the study of Mallikarjuna *et al.* (2000) and Nawaz *et al.* (2003).

Seed Yield

A good supply of P at sowing along with N in splits associated with good root growth and had absorbed plant nutrients and influenced the yield components. This might be the main reason to get significantly increased seed yield. Further, addition of these nutrients at sowing might have influenced the basic soil fertility thereby increased the yield. Similar results were obtained by Nandhagopal *et al.* (1995).

Nutrient management practices had significant influence on the seed yield of sunflower in intercropping system. Split application of recommended dose of nitrogen with basal application of phosphorus and potassium produced higher seed yield than the other nutrient management practices (Table 2). The increase in seed yield might be due to the application of higher level of NPK to intercropping system on area basis. The seed filled percentage is also higher in intercropping system. This result confirmed the findings of Nawaz *et al.* (2003). The increase in seed yield per plant with the increase in N levels could be attributed to the significant increase in yield components like number of filled seeds per head, percentage of filled seeds, 100-seed weight and also significant decrease in number of unfilled seeds. These findings are in conformity with the results of Bindra and Kharwara (1992), Devi *et al.* (1999), Stulin (1999) and Sathiyavelu *et al.* (1994b). Better seed setting and seed filling might be due to the increased metabolic activity. This better metabolic activity might be due to the higher utilization of phosphorus in the presence of nitrogen, which intum might have resulted in increased filled and decreased unfilled seeds per head. These findings are in conformity with the results of Nawaz *et al.* (2004).

Quality Parameters of Sunflower

Oil Content and Oil Yield

In sunflower, higher oil content and oil yield were noticed in split application of recommended dose of nitrogen with basal application of phosphorus and potassium than other nutrient management practices. The increase in oil content and oil yield is attributed to the application of higher level of NPK to intercropping system on area basis. Highest recommended dose of fertilizer level decreased the oil content in sunflower (Table 2). This might be due to the fact that the fertilizer nitrogen caused comparatively greater accumulation of protein in seeds thereby hindering a satisfactory availability of carbohydrates for polymerization into fatty acids, which has lowered the content of oil in seed (Nawaz *et al.*, 2003). Total oil yield obtained with optimum recommended dose of fertilizer to each of the component crops were higher.

Nutrient management practices in intercropping system did not influence the oil content of sunflower significantly. In Groundnut+Sunflower intercropping system there was no significant difference in oil content of sunflower due to different levels of NPK application. This result confirmed findings of Sathiyavelu *et al.* (1994a), who observed that nutrient management practices did not influence the oil content of sunflower. Nawaz *et al.* (2003) stated that application of more than 40 kg N ha⁻¹ increased seed protein content but decreased oil content.

Groundnut Equivalent Yield

Groundnut equivalent yield obtained under intercropping situation due to various nutrient management practices was higher than the yield of pure stand. In 2004, Groundnut+Sunflower intercropping system, application of recommended dose of fertilizer to groundnut with split

Table 3: Effect on nutrient management practices Land Equivalent Ratio (LER) and Groundnut equivalent yield (kg ha⁻¹) of Kharif Groundnut+Sunflower intercropping system

Treatments	Land equivalent ratio			Groundnut equivalent yield (kg ha ⁻¹)		
	a	b	c	GN yield	SF yield	Groundnut EY
	T ₁ -No Fertilizer	0.54	0.33	0.87	960	356
T ₂ -RDF to GN+RDF to SF	0.74	0.46	1.20	1392	496	1872
T ₃ -RDF to GN+No RDF to SF	0.71	0.31	1.02	1366	405	1796
T ₄ -RDF to GN entire systems	0.70	0.39	1.09	1237	429	1824
T ₅ -T ₃ +50% RDF to SF	0.72	0.38	1.10	1295	405	1572
T ₆ -T ₃ +50% RDF to SF+50% N top	0.74	0.41	1.15	1384	411	1914
T ₇ -T ₃ +50% N to SF basal	0.72	0.29	1.01	1340	388	1823
T ₈ -T ₃ +100% PK+50% N to SF basal+50% N top	0.79	0.54	1.21	1465	568	2108
T ₉ -Sole Sunflower	-	1.00	1.00	-	1372	1372
T ₁₀ -Sole Groundnut	1.00	-	1.00	1922	-	1922
SE _d	0.04	0.18	-	89.47	26.72	-
CD (p = 0.05)	0.09	0.39	-	187.4	56.52	-

RDF: Recommended dose of fertilizer; GN: Groundnut; SF: Sunflower; EY: Equivalent yield, GN pod Rs. -12 kg⁻¹ and SF Seed Rs. -15 kg⁻¹

application of recommended dose of nitrogen with the basal application of P and K to component crop recorded higher groundnut equivalent yield of 2198 kg ha⁻¹(Table 3). Higher crop equivalent under intercropping system showed an efficient utilization of resources resulting in better productivity. This result was in accordance with the findings of Chakravarthy *et al.* (2002), who observed that more sunflower equivalent yield when sunflower was intercropped with groundnut. This study as indicated that the base crop yield reduction was well compared with the intercrop yield.

Land Equivalent Ratio (LER)

The LER gives an accurate assessment of the greater biological efficiency of the intercropping situation (Ghosh, 2004). The land equivalent ratio or relative yield provides an ideal base on which comparison could be laid out on any crops; it is commonly criticized because it gives no indication of absolute yields. The result of LER obtained in intercropping system was more than one (Table 3). Under intercropping situation, split application of recommended dose of nitrogen with basal application of P and K to component crop (T₈) gave higher LER of 1.21. LER values indicated that groundnut recorded yield advantage in all intercropping systems due to crop complementarities. This corroborated the findings of several researchers (Willey, 1979; Reddy and Willey, 1981; Ghosh, 2004). The result of LER obtained in intercropping system was more than 1. Under intercropping situation, split application of recommended dose of nitrogen with basal application of P and K to component crop (T₈) gave higher LER of 1.21. The maximum rate of LER under intercropping system might be due to higher productivity per unit area of land under intercropping than monocultures of individual components (Devidayal and Reddy, 1991). This was also in accordance with the findings of Sindagi (1998), who reported that the sunflower grown with groundnut with varying row ratios would be suitable choice for improving the production per unit area.

CONCLUSION

It can be concluded the basal application of 100% fertilizer dose (17:34:54 kg ha⁻¹) to base crop of groundnut rows and basal application of 50% recommended nitrogen (20 kg ha⁻¹) with 100% phosphorus (20 kg ha⁻¹) and potassium (20 kg ha⁻¹) and top dressing of 50% nitrogen (20 kg ha⁻¹) at 21 DAS to sunflower rows was found superior in increasing the productivity of the system in terms of shelling percentage, pod yield, head diameter, seed yield, oil yield and content of groundnut and sunflower crop, equivalent yield and land equivalent ratio.

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