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# Collard–Cowpea Intercrop Response to Nitrogen Fertilization, Redroot Pigweed Density, and Collard Harvest Frequency

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***Abstract*. Field experiments were conducted in 1992 and 1993 to determine the effect of N fertility, cropping system, redroot pigweed (*Amaranthus retroflexus* L.) density, and harvesting frequency on collard (*Brassica oleracea* var. *acephala* D.C) and cowpea [*Vigna unguiculata* (L.) Walp.] growth. The N fertilization regimes were 0, 80, 160, and 240 kg·ha$^{-1}$, applied as urea in a split application. Four weeks after crop planting, redroot pigweed was seeded at 0, 300, and 1200 seeds/m$^2$. Between weeks 6 and 12, collard leaves were harvested at 1- to 3-week intervals. Year, N fertility, and cropping system interacted to determine collard leaf number and mass. For example, in 1992, with N at 160 kg·ha$^{-1}$, collards intercropped had more total leaf mass than those monocropped. Pigweed density had no effect on collard yields, which were greatest from the 3-week harvest frequency. Cropping system and pigweed density interacted to determine cowpea vine length, shoot dry mass, and branching. The high density of pigweed caused a 56% reduction of cowpea dry mass in 1992.**

The majority of farmers in developing countries practice intercropping (Coolman and Hoyt, 1993; Horwith, 1985; Perrin, 1977). In developed countries, mechanization caused intercropping to be inconvenient, leading to its abandonment (Horwith, 1985). Recent research indicates that intercropping may be compatible with mechanized agriculture and could provide an alternative to monocropping, especially for small, resource-poor farms (Horwith, 1985; Santalla et al., 1995). Cowpeas (blackeye peas) and collards (kale) are widely grown on small, resource-poor farms in the United States and Kenya. Cowpea is an important protein source throughout the tropics, and the seed and young leaves are consumed (Blade et al., 1992; Imbamba, 1973). Collard leaves are a popular leafy green, especially for the urban poor of Kenya (Itulya, 1995). In Africa, cowpea is grown with cereals, vegetables (including collards), perennial legumes, and root crops (Gethi and Khaemba, 1991; Rachie and Roberts, 1974). Associate crops of collards include maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) (Itulya, 1995). Intercropping studies have concentrated on field crops (Olasantan, 1991), and, to our knowledge, no information is available on intercropping collards with cowpeas.

Intercropping may increase the sustainability of collard and cowpea cropping systems, especially for small, resource-poor farms. Yields are more stable with intercropping than with monocropping because the yield of one crop compensates for reductions in yield of the other (Horwith, 1985; Trenbath, 1993; Vandermeer, 1989). The greater yield stability reduces risks (Horwith, 1985) and minimizes the potential for total crop failure (Pearce and Edmondson, 1982; Rao and Willey, 1980).

Collards and other leafy green vegetables are often heavily fertilized with N (Thompson and Doerge, 1995). Intercropping collards with a legume can improve N-use efficiency because the two crops use different N pools (Coolman and Hoyt, 1993) and the legume can release biologically fixed N to the nonlegume (Clark and Myers, 1994; Reid, 1983; Senaratne et al., 1995). Thus, the nonlegume requires less N to produce its best yield (Olasantan, 1991). Absorption of mineral N by the nonlegume reduces soil N pools, thus stimulating $N_2$ fixation by the legume (Waterer et al., 1994).

Weeds constitute a major constraint to small, resource-poor farms because of the labor needed to hand-weed and the expense or unavailability of alternative methods of control (Ayeni et al., 1984; Horwith, 1985). An intercrop can lessen weed competition by establishing an earlier and more complete canopy than the monocrop (McFadden, 1991; Midmore, 1993; Olasantan et al., 1994). Increased yields from intercropping for weed control are most evident in resource-poor farming systems (Midmore, 1993).

Nitrogen fertilization, weed control, and harvest frequency can be tailored to favor the more important component of an intercrop. At low soil N, the ability of cowpea to fix $N_2$ may give it a competitive advantage over the collards. Increased N fertilization could shift the competitive ability and balance of yield to favor the collards (Fukai and Trenbath, 1993; McFadden, 1991; Midmore, 1993; Ofori and Stern, 1987; Waterer et al., 1994). Nitrogen fertilization, along with early-season weed control, allows rapid crop establishment and growth, which is critical for the crop to suppress late-emerging weeds (Ayeni et al., 1984; Coolman and Hoyt, 1993; McFadden, 1991). Collard leaves can be harvested several times over the entire growing period (Chahira and Itulya, 1994). Agronomic practices that maximize ground cover, such as infrequent harvesting, should improve weed suppression (Midmore, 1993).

Our objective was to develop a system to maximize collard and cowpea growth while minimizing weed competition. Therefore, we evaluated the impact of N fertilization, cropping system, redroot pigweed density, and collard harvesting frequency on collard and cowpea growth.

## Materials and Methods

A field study was conducted during the 1992 and 1993 growing seasons at the Univ. of Illinois Vegetable Research Farm in Champaign. The soil was a Drummer silt loam (fine montmorillonitic, mesic, Aquic Arguidoll) with 30 ppm of P, 128 ppm of K, 0.15% N, and 3.1% organic matter. The previous September, the site was moldboard plowed and disked. Final spring preparation was by rotary tillage. 'California Blackeye No. 5' cowpea was drilled at a spacing of 45 cm between rows and 10 cm within the row on 6 May 1992 and 24 May 1993.

The experiment was a factorial combination of 1) N fertility, 2) cropping system (monocrop or intercrop), 3) redroot pigweed density, and 4) collard leaf harvesting frequency. The experimental treatments were replicated three times in a split-plot design. Nitrogen fertility levels were the main plots and combinations of the other three factors were the subplots. Subplots were 4 × 9 m$^2$. The subplots contained either four rows of collard and eight rows of cowpea, or four rows of collard plus eight rows of cowpea. In intercropped subplots, one row of collard was alternated with two rows of cowpea.

'Champion' collard transplants were established in 72-cell flats filled with a mixture of 1 peat moss : 1 horticultural grade vermiculite (w/w) (Metro-mix 200; Grace Sierra Horticultural Product Co., Milpitas, Calif.). They were grown for 5 weeks in standard greenhouse conditions as described in Perez and Masiunas (1990). Immediately after cowpea seeding, the collards were mechanically transplanted in rows spaced 90 cm apart. The within-

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row spacing was 50 cm. The cropping systems were collard monocrop, cowpea monocrop, and collard–cowpea intercrop. The collard monocrop had 22,000 plants/ha and the cowpea monocrop had 222,000 plants/ha. The intercrop had two rows of cowpea for every row of collards and plant populations were 22,000 and 148,000 plants/ha for collard and cowpea, respectively.

Nitrogen treatments were 0, 80, 160, and 240 kg·ha$^{-1}$ as urea (46% N). The N was split with one-half at planting and the other half 4 weeks after crop establishment. Redroot pigweed seed was mixed with silica sand and hand-planted in clumps within the crop row at 0, 300, and 1200 seeds/m$^2$, giving final densities after thinning of about 0, 100 (low), and 800 (high) pigweed plants/m$^2$. Redroot pigweed is representative of broadleaf weed species common in both Kenya and the United States. The herbicide *N,N*-diethyl-2-(1-naphthalenyloxy)propanamide (napropamide) was surface-applied at 2.24 kg·ha$^{-1}$ after pigweed emergence and irrigated into the soil. Emerged weeds other than redroot pigweed were hand-removed. About 2 cm of water per week was applied either as rainfall or by sprinkler irrigation. Other cultural practices simulated small farm production for fresh-market sales.

The first collard leaf harvest was 6 weeks after transplanting and harvest continued at 1-, 2-, or 3-week intervals until termination of the experiment at 12 weeks. In each plot, eight plants were randomly chosen from the center two rows; these plants were used for all harvests. All fully expanded leaves were removed, counted, and their masses determined.

In central Illinois, cowpeas do not flower and produce seed; thus, only shoot growth was determined. All cowpea plants in the center two rows were harvested at 12 weeks, and cowpea vine lengths measured and branches counted. The plants were oven-dried at 50 °C for 4 d and their mass determined.

Data were subjected to analysis of variance using the general linear model procedure of SAS (SAS Institute, Cary, N.C.). Treatment interactions were determined and, where possible, data were combined. When significant treatment differences occurred, the means were separated using Fisher's protected least significant difference test (LSD, $P \leq 0.05$). If the effects of N fertility or collard leaf harvest frequency were significant, then regression analysis was performed.

## Results and Discussion

*Collards.* The N fertility × cropping system interaction affected the number of leaves (Table 1). In 1992, N rate affected the number of leaves harvested from the monocrop but not the intercrop (Table 2). The numbers of leaves harvested at N rates of 0 and 240 kg·ha$^{-1}$ were similar in the monocrop and intercrop. The monocrop with N at 160 kg·ha$^{-1}$ had fewer leaves (579,000 leaves/ha) than with N at 0 and 240 kg·ha$^{-1}$. In 1993, N did not affect number of leaves harvested in the monocrop. The later planting date in 1993 may have reduced growth, the number of leaves harvested, and the differences between treatments.

Nitrogen did not have a consistent effect on number of collard leaves; numbers varied depending on year and cropping system. Thompson and Doerge (1995) reported that N increased collard yields in a monocrop, but Clark and Myers (1994) reported no effect in cowpea–pearl millet or cowpea–amaranth intercrops. The inconsistent effect of N on collard yields may be caused by either the inherent fertility of our site or the release of N by cowpea. Cowpea can excrete N from its nodulated root system (Clark and Myers, 1994; Senaratne et al., 1995) or through decomposition of its roots, nodules, and leaves (Reid, 1983; Senaratne et al., 1995).

In 1992, N fertility and cropping system interacted to affect both mass per leaf and the total mass of collard leaves. The trends were similar to those for leaf number. With N at 160 kg·ha$^{-1}$, collards intercropped had more total mass than those monocropped. For the intercrop, mass per leaf with N at 160 kg·ha$^{-1}$ was greater than at 0 or 240 kg·ha$^{-1}$. In 1993, N fertility × cropping system interaction was nonsignificant. Intercropping collards with cowpeas did not consistently reduce the amount of N needed to produce the greatest total leaf mass or mass per leaf. Our results differ from those of Olasantan (1991), who reported that less N was needed for tomato or okra when intercropped with cowpea than in monocrops. Collards may require more N than tomatoes or okra. Also, cowpea at our location may have been less efficient in fixing atmospheric N than in Nigeria, the site of Olasantan's research.

In 1992, less frequent harvesting of collards increased yield (Table 3). For example, collard leaf numbers were greatest when harvested once every 3 weeks (719,000 leaves/ha) and least when harvested once a week (630,000 leaves/ha). In 1993, harvest frequency and N fertility interacted to determine number of collard leaves. At 0 and 80 kg·ha$^{-1}$ of N, harvesting every 3 weeks resulted in the greatest number of leaves (data not shown). Frequent leaf harvests may not allow collard plants adequate time to produce new leaves. This differs from a previous study (Chahira and Itulya, 1994), in which the greatest number of leaves were obtained with a high harvest frequency. The difference in cultivars and climatic conditions may explain the dissimilar results from the two studies.

Harvest frequency affected total leaf mass (Table 3). Collard total leaf mass was reduced by harvesting every week, regardless of the fertility or cropping system. Chahira and Itulya (1994) also reported that frequent harvesting reduced leaf mass. This supports our contention that frequent harvesting does not allow the plants adequate time to recover and produce new leaf tissue. Increasing N cannot prevent such reduced yield.

Table 1. Analysis of variance for number and mass of collard leaves harvested and cowpea foliage mass, vine length, and number of branches in 1992 and 1993.

| Source of variation | Significance: Collard No. | Collard Mass | Cowpea L[z] | Cowpea Br[y] | Cowpea Mass[x] |
|---|---|---|---|---|---|
| | | | *1992* | | |
| Nitrogen fertility (NF) | NS | NS | NS | NS | NS |
| Cropping system (CS) | NS | NS | NS | NS | NS |
| NF × CS | * | * | NS | NS | NS |
| Pigweed density (RPD) | NS | NS | NS | *** | *** |
| NF × RPD | NS | NS | NS | ** | NS |
| CS × RPD | NS | NS | NS | NS | NS |
| NF × CS × RPD | NS | NS | NS | NS | NS |
| Harvest frequency (HF) | *** | ** | NS | NS | NS |
| NF × HF | NS | NS | * | NS | NS |
| CS × HF | NS | NS | NS | NS | NS |
| RPD × HF | NS | NS | NS | NS | NS |
| NF × CS × HF | NS | NS | NS | NS | NS |
| NF × RPD × HF | NS | NS | NS | NS | NS |
| NF × CS × RPD × HF | NS | NS | NS | NS | NS |
| | | | *1993* | | |
| NF | NS | NS | * | NS | NS |
| CS | * | NS | NS | NS | NS |
| NF × CS | * | NS | * | * | NS |
| RPD | NS | NS | * | NS | ** |
| NF × RPD | NS | NS | NS | * | NS |
| CS × RPD | NS | NS | NS | NS | ** |
| NF × CS × RPD | NS | NS | NS | * | NS |
| HF | NS | * | * | NS | NS |
| NF × HF | * | NS | NS | NS | NS |
| CS × HF | NS | NS | NS | NS | NS |
| NF × CS × HF | NS | NS | NS | NS | NS |
| RPD × HF | NS | NS | NS | NS | NS |
| NF × RPD × HF | NS | NS | NS | NS | NS |
| NF × CS × RPD × HF | NS | NS | NS | NS | NS |

[z]Length of cowpea vines 12 weeks after planting.
[y]Number of branches per plant.
[x]Shoot dry mass.
NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001, respectively.

Table 2. Effect of N application and cropping system on collard leaf yields, averaged over harvest frequency.[z]

| Cropping system | N applied ($kg\cdot ha^{-1}$) | Leaves (no.) 1992 (thousands/ha) | Leaves (no.) 1993 (thousands/ha) | Mass Total 1992 ($Mg\cdot ha^{-1}$) | Mass Total 1993 ($Mg\cdot ha^{-1}$) | Mass Per leaf 1992 (g) | Mass Per leaf 1993 (g) |
|---|---|---|---|---|---|---|---|
| Monocrop | 0 | 686 ab[y] | 564 ab | 16.0 ab | 11.0 | 23.0 ab | 19.5 |
| | 80 | 633 bc | 563 ab | 13.7 ab | 14.0 | 21.6 bc | 24.9 |
| | 160 | 579 c | 622 a | 9.1 b | 15.9 | 15.7 c | 25.6 |
| | 240 | 710 ab | 585 ab | 18.1 ab | 13.3 | 25.5 ab | 22.7 |
| Intercrop | 0 | 717 ab | 587 ab | 15.9 ab | 13.0 | 22.2 bc | 22.1 |
| | 80 | 738 a | 536 b | 18.1 ab | 11.3 | 24.5 ab | 21.1 |
| | 160 | 673 a–c | 560 ab | 20.1 a | 13.6 | 29.9 a | 24.3 |
| | 240 | 756 a | 553 b | 16.9 ab | 12.9 | 22.4 bc | 23.3 |

[z]No significant linear or quadratic effects of N fertility except number of leaves for the intercrop in 1992 ($Y = 752 - 0.0264X + 2 \times 10^{-7}X^2$, where Y = number of leaves; X = N fertility; $r^2 = 0.86$).
[y]Mean separation within columns by Fisher's LSD at $P \leq 0.05$.

In 1992, but not 1993, frequent leaf harvest reduced leaf mass. The mass per leaf was doubled when collards were harvested every 3 weeks rather than once a week (Table 3). The lack of effect of harvesting frequency on leaf size in 1993 was probably due to the warmer temperatures that stimulated growth.

Neither redroot pigweed density nor its interactions affected collard leaf yield (Table 1). This result was surprising and indicates that collard is an efficient competitor. The lack of interaction between cropping system and pigweed density interaction on leaf yield suggests that collard competitive ability was similar in both the monocrop and intercrop. Since the interaction of N fertility with pigweed density was not significant, N was not a limiting factor in collard–weed competition.

*Cowpeas*. Pigweed density (1992) or the interaction between cropping system and pigweed density (1993) affected cowpea shoot dry mass (Table 4). In 1992, cowpea mass was greatest with no pigweed and least with the high pigweed density. In 1993, the monocropped cowpea plants were largest in the low pigweed density and the intercropped cowpea plants were largest with no pigweed. The intercropped plants with no pigweed were about twice as large as those in either pigweed density. Intercropping cowpea with collards did not make cowpea more competitive nor did it reduce pigweed growth (data not shown). Instead, intercropping collards with cowpea reduced the ability of cowpea to tolerate the low density of pigweed. Blade et al. (1992) also reported that cowpea growth was severely depressed by competition with other plants.

Nitrogen fertilization did not affect cowpea shoot dry mass. This differs from collards where the N fertility and cropping system interacted to determine yields. Collards use mineral N, while cowpeas can fix atmospheric N (Coolman and Hoyt, 1993). Increasing N did not shift the competitive advantage to favor the collards. This differs from other reports where applied N favored the nonlegume (Fukai, 1993; McFadden, 1991; Midmore, 1993). The hot summer growing conditions in Illinois may favor growth of cowpea more than that of collards.

Cowpea plants branched more in 1992 than in 1993. In 1992, the greatest branching was at an N rate of 80 or 160 $kg\cdot ha^{-1}$ with no pigweed, or with N at 160 $kg\cdot ha^{-1}$ and low pigweed density (Table 5). The high rate (240 $kg\cdot ha^{-1}$) of N or the presence of pigweed (with the exception of the low density at N rate of 160 $kg\cdot ha^{-1}$) inhibited branching. In 1993, N fertility, pigweed density, and cropping system interacted to determine branching. The greatest branching in the monocrop was at the low density of pigweed with no N. In the monocrop at low pigweed density, N reduced cowpea branching from three branches per plant at 0 N to no branches with N at 160 $kg\cdot ha^{-1}$. Nitrogen increased pigweed growth, causing cowpea vines to grow longer and to remain unbranched. With N at 160 $kg\cdot ha^{-1}$ and either the low or high density of pigweed, intercropped cowpea branched more than did monocropped cowpea. Intercropping with collards resulted in a more open canopy that encouraged more branching than did monocropping.

Cowpeas in 1993, but not 1992, became shorter as redroot pigweed density increased (data not shown). For example, cowpea vine length in the monocrop with N at 160 $kg\cdot ha^{-1}$ was 103 cm with no pigweed and 47 cm with a high density of pigweed. Nitrogen fertility and cropping system also interacted to affect cowpea vine length (Table 6). In 1992, vines of monocropped cowpeas at 0 N were longer than vines at any other rate of N. In 1993, the greatest vine length was with N at 80 $kg\cdot ha^{-1}$ and the least was with N at 0 or 160 $kg\cdot ha^{-1}$. The response of intercropped cowpeas differed. In 1992, N rate did not affect vine length, while, in 1993, the greatest vine length was with no N and least with N at 80 and 240 $kg\cdot ha^{-1}$. The addition of N favored growth of collards and pigweed over growth of cowpea.

Cowpeas were sensitive to competition with pigweed while collards were not. Ayeni et al. (1984) reported that cowpea yields in an intercrop were reduced more by full-season weed interference than were maize yields. Weeds must be controlled initially to enable the intercrop to form sufficient canopy to suppress them (Ayeni et al., 1984; Coolman and Hoyt, 1994).

The three cropping systems (monocropped collard, monocropped cowpea, and collard–cowpea intercrop) responded to the management methods. Cowpea was more sensitive to pigweed competition and less dependent on N fertilization than collards. Growth of pigweed or collards was increased more by N than was vine elongation of cowpea. Nitrogen fertility or the intensity of weed control can be used to favor either cowpea or collards in an intercrop. For example, weed control is more important, and N fertilization is less important, for optimal growth of cowpea than of collards. This information will allow small, resource-poor farms to use their labor and inputs more efficiently. Optimizing cultural practices will improve yields and reduce risks.

Table 3. The effect of harvest frequency on collard leaf yields, averaged over cropping system and N fertility.[z]

| Harvest frequency (weeks) | Leaves (no.) 1992 (thousands/ha) | Leaves (no.) 1993 (thousands/ha) | Mass Total 1992 ($Mg\cdot ha^{-1}$) | Mass Total 1993 ($Mg\cdot ha^{-1}$) | Mass Per leaf 1992 (g) | Mass Per leaf 1993 (g) |
|---|---|---|---|---|---|---|
| 1 | 630 b[y] | 541 b | 9.06 c | 12.1 b | 14.3 a | 22.4 |
| 2 | 711 a | 555 b | 15.9 b | 13.5 a | 22.4 b | 24.3 |
| 3 | 719 a | 605 a | 21.0 a | 13.7 a | 29.2 c | 22.6 |

[z]No significant linear or quadratic effects of harvest frequency in 1992 on number of leaves and in 1993 on any parameter. For 1992, $Y_1 = -0.531 + 0.165X$, where $Y_1$ = total leaf mass; X = harvest frequency; $r^2 = 0.78$, and $Y_2 = -0.941 + 0.134X$, where $Y_2$ = mass/leaf; X = harvest frequency; $r^2 = 0.91$.
[y]Mean separation within columns by Fisher's LSD at $P \leq 0.05$.

Table 4. The effect of pigweed density (1992) or the interaction of cropping system and pigweed density (1993) on cowpea shoot dry mass (g/plant),[z] averaged over collard harvest frequency (intercrop only) and N fertility.

| Pigweed density | 1992[y] | 1993 Monocrop | 1993 Intercrop |
|---|---|---|---|
| None | 45.3 a[x] | 26.8 b | 40.0 a |
| Low | 31.5 b | 38.5 a | 22.6 b |
| High | 19.9 c | 27.6 b | 19.0 b |

[z]Includes leaves and stems.
[y]Cropping system effect significant; data averaged for monocrop and intercrop.
[x]Mean separation within columns by Fisher's LSD at $P \leq 0.05$.

Table 5. The effect of N fertility and pigweed density on cowpea branching (no. branches/plant), averaged over collard harvest frequency (intercrop only).[z]

| N | Pigweed density | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| fertility | None | | | Low | | | High | | |
| | | 1993 | | | 1993 | | | 1993 | |
| (kg·ha$^{-1}$) | 1992[y] | Mono[x] | Inter | 1992 | Mono | Inter | 1992 | Mono | Inter |
| 0 | 1.5 bc[w] | 0.0 f | 1.6 b | 0.3 d | 3.0 a | 0.1 ef | 0.8 cd | 0.7 d–f | 0.2 ef |
| 80 | 2.1 ab | 1.3 b–d | 0.1 ef | 0.4 d | 0.3 ef | 0.6 d–f | 0.5 d | 0.4 ef | 0.6 d–f |
| 160 | 2.5 a | 0.0 f | 0.7 d–f | 1.8 ab | 0.0 f | 1.5 bc | 0.3 d | 0.0 f | 1.2 b–d |
| 240 | 1.5 bc | 0.7 d–f | 0.8 c–e | 0.6 d | 0.7 d–f | 0.8 c–e | 0.2 d | 0.7 d–f | 0.1 ef |

[z]Cropping system effect significant in 1993, but not in 1992.
[y]Averaged over cropping system.
[x]Mono = cowpea monocrop; Inter = cowpea–collard intercrop.
[w]Mean separation within years by LSD at $P \leq 0.05$.

Table 6. The interaction of N fertility and cropping system on cowpea vine length (cm), averaged over pigweed density.[z]

| N | Cropping system | | | |
|---|---|---|---|---|
| fertility | Monocrop | | Intercrop[y] | |
| (kg·ha$^{-1}$) | 1992 | 1993 | 1992 | 1993 |
| 0 | 99 a[x] | 78 b | 56 | 125 a |
| 80 | 74 b | 147 a | 75 | 66 b |
| 160 | 75 b | 77 b | 72 | 106 ab |
| 240 | 70 b | 112 ab | 65 | 65 b |

[z]No significant linear or quadratic effects of N fertility on vine length in the monocrop (both years) or the intercrop (1993). Regression equation in 1992 is $Y = -122 + 0.0466X - 4.3 \times 10^{-6}X^2$, where Y = vine length in cm; X = N rate; $r^2 = 0.85$.
[y]Averaged over collard harvest frequency.
[x]Mean separation within columns by Fisher's LSD at $P \leq 0.05$.

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