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Amaranth Seed Rate Effect on Biological Efficiency of Maize-Leaf Amaranth Intercropping Systems

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ABSTRACT

Maize (TZSR-Y variety) sown at 75x25 cm and leaf amaranth (NH Ac 23) seed rates at 2, 4 and 6 kg.ha^{-1} drilled in rows 30 cm apart were grown sole and as intercrops in four replications and laid out in randomized complete block design during the rainy season of 2009 and 2010 on the Teaching and Research Farm, Ekiti State University, Ado-Ekiti, Nigeria. Amaranth yield was determined as weight of >15 cm tall plants uprooted weekly from one month old for four harvests; weight of shoots repeatedly cut at 15 cm fortnightly; and weight of seeds from mature inflorescences after threshing. Maize cobs were harvested dry, shelled, and sun-dried and weighed. Cropping system had no significant effect on leaf amaranth yield obtained by uprooting and repeated cutting but seed yield was higher in sole cropping in 2009. Yield obtained by uprooting and repeated cutting and seed yield increased with amaranth seed rate. In sole and intercropping systems, optimum marketable amaranth yields were obtained at 4 and 6 kg.ha^{-1} by uprooting and 2 and 4 kg.ha^{-1} by repeated cutting. Intercropping slightly depressed maize grain yield and the reduction was higher as amaranth seed rate increased. Land Equivalent Ratio exceeded 1.0 in all intercropping systems and was highest at 6 and 4 kg.ha^{-1} seed rate for marketable yield and seed yield, respectively at the established maize population.

Introduction

The leaf vegetable most consumed in Nigeria is amaranth (*Amaranthus sp*), known as green (tete or efo tete, *Yoruba*; alaffu or aleho, *Hausa* and inine, *Igbo*) and usually grown in combination with food crops, notably maize (Denton and Olufolaji, 2000). This intercropping, the predominant practice in the traditional smallholder food production systems of the tropics particularly in Nigeria, should be exploited for the output expansion needed to meet the growing demand for maize as an energy-rich food for human consumption, livestock feed and industrial raw materials (Fakorede, 2001) and amaranth edible leaves which have enormous dietary and nutrition health potentials (Grubben, 2004). Liu and Stützel (2004) noted that amaranth should be intercropped with maize to improve the nutrient status of households because of the nutritional status and adaptability to tropical and sub-tropical climates. Amaranth leaves contain 17.5-38.3% protein on dry weight basis 5% of which is lysine, an essential amino acid lacking in diets based on cereals and root and tubers (Kauffman and Weber, 1990). The leaves taste much like spinach but are nutritionally superior containing three times more calcium (Ca), niacin and vitamin C than spinach and 18 times more vitamin A, 13 times more vitamin C, 20 times more Ca and 7 times more iron than lettuce (Mnkeni, 2005).

The nature and extent of plant-plant interactions determine intercropping advantages. Therefore, consideration is usually given to compatibility of component crops through manipulation of population densities (spacing, planting pattern and stand geometry) in order to maximize productivity (Okigbo and Greenland, 1976). Patches of amaranth seedlings established by direct seeding (broadcasting) or transplanted, especially during thinning out, are found in the traditional smallholder food crop farms. These methods of establishment have the disadvantages of poor seedling emergence and uneven stands (Grubben, 1979) and high labour requirements (170 man-days.ha^{-1}) (Olufolaji and Tayo, 1989a), respectively. The suggested alternative is to plant dense stands using 1.2-3.5 kg.ha^{-1} seed rate at 5-10 cm on 90 cm rows for harvesting by uprooting or 15-30 cm for repeated cutting of stem tops (O'Brien and Price, 2008). Palada and Chang (2003) noted that direct seeding can be by uniform broadcasting or sowing seeds (1 g.m^{2}) at 5 cm in 10 cm rows on the beds. Drilling the seeds minimizes these problems and the available recommendation is to drill 2-6 kg.ha^{-1} amaranth seeds in 20 cm rows apart on 1.0-1.5 m wide beds for harvesting by uprooting (Olufolaji and Denton, 2000; Grubben, 2004).

Amaranth is one of the crops that had traditionally been intercropped with maize in patterns distinguished as broadcast after the maize was sown in the tropical zone of meso-America; and sowing in rows parallel to maize, as border or perimeter plants, and sowing or transplanting in same row with maize in the temperate zone for green vegetable and grain harvested later (Early, 1990). The feasibility is based on the fact that up to 45-55 days after planting when maize enters the reproductive phase, it does not make optimal use of resources and such would be effectively utilized by short-duration crops which complete their life cycles within the period (Thavaprakaash and Velayudham, 2007). Thus, in maize-based intercropping systems, selection of crops with the appropriate plant structure and growth pattern, especially those maturing before the peak growth period of maize, would assume greater attention. Leaf amaranth, ready for harvesting 20-45 days after sowing depending on cultivar (Palada and Chang, 2003), can be grown in-between maize rows

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to meet the demand for this vegetable without any reduction in cultivated land area. Farmers should adopt the technologies that optimize output in maize-amaranth intercropping systems. These are not yet available as information is scanty on leaf amaranth-maize intercropping in Nigeria but successful mixture of transplanted grain amaranth seedlings (Manga *et al*., 2003; Olorunnisomo and Ayodele, 2009) and direct-seeded leaf amaranth (Makinde *et al*., 2009) with maize, as indicated by higher biological productivity compared to the individual sole crops, had been reported. Thus, relevant studies on the feasibility of maize-leaf amaranth mixtures must be carried out, especially those which emphasize component crop populations. This recognizes that maximum productivity in intercropping would be achieved when inter- and intra-plant competitions are minimal for growth-limiting factors and the density of each crop adjusted to minimize competition between them (Huxley and Miangu, 1978). The recommended spacings for maize in cassava and yam-melon mixtures are 90x90 cm and 100x100 cm (at 2 plants.hill^{-1}) to attain 24,000 and 20,000 plants.ha^{-1} respectively (IAR&T, 1991). These are inadequate for intercropping with leaf amaranth as observed by Ayodele *et al* (2013) that maize established at 50,000 plants.ha^{-1} gave the best mixture yields of maize and leaf amaranth and suggested using the sole maize spacing of 75x25 cm or 90x20 cm (53,330 or 55,550 plants.ha^{-1}) in combination with the appropriate amaranth seed rate. This study was carried out to determine the amaranth seed rate at which to maximize productivity and returns for maize-leaf amaranth intercropping systems.

Materials And Methods

The experiments were carried out on the Teaching and Research farm, Ekiti State University, Ado-Ekiti in Nigeria (longitude 5°14'E; latitude 7°42'N) during the early rainy seasons of 2010 and 2011. The site is about 456 m above sea level and experiences a warm sub-humid tropical climate characterized by 1,367 mm annual rainfall received in 112 rainy days, mean temperature range of 25-32°C and average 5 hours daily sunshine. The land, a sandy loam which had been previously cultivated to arable crops (maize/cassava in 2008-2009 followed by cowpea on late 2009) was ploughed and harrowed.

Three leaf amaranth seed rates: 2. 4 and 6 kg.ha^{-1} were combined with maize sown at 75x25 cm spacing to attain 53,330 plants.ha^{-1} into seven treatments: maize alone; maize + 2 kg.ha^{-1} amaranth seeds; maize + 4 kg.ha^{-1} amaranth seeds; maize + 6 kg.ha^{-1} amaranth seeds; 2, 4 and 6 kg.ha^{-1} amaranth seeds. The treatments were replicated four times and arranged in randomized complete block design. Each plot was 3x1.5 m, separated by 1 m wide paths. Amaranth seeds were mixed with dry fine sand and drilled in rows 20 cm apart. Maize-amaranth plots contained 7 rows of amaranth to 2 rows of maize such that there were 3 rows between the maize rows and each bordered on the outside by 2 rows of amaranth. Compound fertilizer NPK 15-15-15 fertilizer at 200 kg.ha^{-1} was applied 2 weeks after sowing (WAS) by banding on one side of amaranth rows and on two sides of each maize plant. The plots were kept weed-free by manual weeding as and when necessary.

Each plot was divided into three equal portions for harvesting the amaranth: weight of uprooted seedlings at least 15 cm tall as from 4-5 weeks for four weekly harvests; weight of shoots repeatedly cut at 15 cm height and at 2-3 weeks intervals; and weight of seeds threshed from inflorescences cut at 12 WAS and dried. Dry maize cobs were harvested, de-husked and sun-dried. The cobs were shelled and the grains further sun-dried and weighed. The yield data were scaled to per ha basis, analyzed with the variance ratio and the means separated by the procedure described in Steel *et al*. (1997). The land equivalent ratio (LER) was calculated for biological efficiency as:

$$\frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

where Y_{ab}, Y_{ba} are the individual crop yields in intercropping; and

Y_{aa}, Y_{bb} are the sole crop yields (John and Mini, 2005).

Results And Discussion

Table 1 shows the number of emerged leaf amaranth seedlings at 14 DAS in the sole and intercropping systems. The number of seedlings increased linearly from 1.2x10^6 to 2.8x10^6 plants.ha^{-1} between 2 to 6 kg.ha^{-1} seed rate, and representing 62.5 and 133.3% more between 2 and 4, and 2 and 6 kg.ha^{-1} seed rates, respectively in 2010. The increase was also linear in 2011 being from 0.91x10^6 to 1.82x10^6 between 2 and 6 kg.ha^{-1} seed rate. Intercropping resulted in 6.4% more seedlings than in the sole crop in 2010 but this increase was not significant while the increase was 7.5% in 2011. The 6 kg.ha^{-1} seed rate produced 2.3x10^6 and 3.3x10^6; 1.66x10^6 and 1.98x10^6 seedlings under sole and intercropping systems for 2010 and 2011, respectively which differed significantly (P=0.05) from lower rates. Only the 2 kg.ha^{-1} seed rate produced significantly lower seedlings than the higher rates which were not different in 2010 while the order was 2 < 4 < 6 kg.ha^{-1} in 2011. O'Brien and Price (2008) observed that the recommended seed rate of 1.2-3.5 kg.ha^{-1}, depending on soil and soil moisture conditions, produces so many seedlings that a large number can be lost through self-thinning without reducing yield and which may remain constant across the 0.3-4.5 kg.ha^{-1} range. The seedling population obtained with the 6 kg.ha^{-1} seed rate is higher than expected 1.8 million plants at 7.5x7.5 cm spacing for maximum productivity of transplanted amaranth harvested by uprooting or once-over cutting (Grubben, 2004). Amaranth seeds are small in size (0.5-1.00 mm in diameter) and weight (1,500-2,000.g^{-1}) and so the 6 kg.ha^{-1} seed rate should produce 12x10^6 plants. The populations of 2.3-3.3x10^6 and 1.66-1.98x10^6 plants obtained in 2010 and 2011 respectively indicate 19.2-27.5% and 13.8-16.5% seedling emergence. Olufolaji and Tayo (1989a) obtained low average seedling survival % in 6 kg.ha^{-1} drilled amaranth which is comparable with the values in this study and suggested that small seed size and weight contribute to the difficulties in field establishment of leaf amaranth. The seeds cluster which would cause high seedling mortality from overcrowding while splashing and splattering actions of raindrops and surface runoff can easily wash seeds away especially when not covered or incorporated with soil. Besides, there is uneven maturity of the indeterminate inflorescence in which seeds from the basal, middle and apical portions are in different stages of development and so would cause low germination and irregular seedling emergence. Also, the small seeds have limited food reserves to support growth and emergence such that sowing depth and frequent watering, especially from rainfall that causes soil crusting and compaction of the drill rows in loams to sands, would lead to poor seedling establishment.

The effects of cropping systems, amaranth seed rates and methods of harvesting on marketable yield of vegetable amaranth are shown in Table 2. Marketable yield of amaranth obtained by uprooting was not affected by cropping system in 2010 but yield was significantly (P=0.05) higher in the sole crop in 2011 while the yield obtained by repeated cutting was not affected by cropping system in both years. Leaf amaranth seedlings grow rapidly and attain marketable size within 28-45 days during which there is under-utilization of production resources by companion maize plants and so competition is minimal (Thavaprakaash and Velayudham, 2008). However, the effect of maize on amaranth can be pronounced depending on the time of inclusion and extent of interaction between the two component crops. Observations on-farm show severe negative effects when maize had reached peak vegetative growth or tasselled as the bigger plants would shade the amaranth and deplete the soil of nutrients while the leaf amaranth would be more susceptible to disease and pest attack. In this study, maize and amaranth were seeded on the same day in adjacent rows and the amaranth being aggressive grew rapidly and was not affected by the few maize stands. Makinde *et al*. (2009) observed that seeding amaranth in 2 to 3-week old maize fields reduced yield of the intercropped amaranth. In maize-grain amaranth mixture, leaf area of the amaranth increased because maize was already established while the grain amaranth was trying to produce more leaves in order to be competitive (Manga *et al*., 2003).

Marketable yield increased consistently with amaranth seed rate across sole and intercropping systems in the two years. The highest yield of uprooted sole amaranth (15.60 MT.ha^{-1}) was obtained at 6 kg.ha^{-1} seed rate but which did not differ from the yield at 2 kg.ha^{-1} in 2010 while the highest yield at 6 kg.ha^{-1} did not differ from 4 kg.ha^{-1} in 2011. Olufolaji and Tayo (1989a) had reported higher yields of sole amaranth by uprooting as seed rate increased from 2 to 6 kg.ha^{-1}. Yield obtained by repeated cutting was highest at 6 kg.ha^{-1} in 2010 but which did not differ from the 4 kg.ha^{-1} rate whereas the highest yield obtained at 6 kg.ha^{-1} did not differ from the lower rates in 2011. For the sole and intercropping systems, the best yield came from 4 and 6 kg.ha^{-1}; 2 and 6 kg.ha^{-1} rates, respectively in 2010 and 2011. Marketable yield obtained from repeated cutting was lower than from uprooting which differs from the results obtained by Olufolaji and Tayo (1989b). This may be due to a decrease in the number of surviving plants in response to difficulty of recovery from repeated cutting and that the harvested shoots reduced in size with time whereas roots, stems and leaves were weighed in the uprooted whole plants.

The effects of cropping system and amaranth seeding rate on amaranth and maize grain yields are shown in Table 3. Amaranth seed yield was significantly (P=0.05) higher in the sole crop than the intercrop in 2010 but the higher yield in 2011 was not significant. The lower yield in intercrop probably resulted from the longer period of interaction between the component crops which would result in greater competition. Since the sole crop had a lower population, there would be better individual plant performance and greater inflorescence development. Seed yield increased linearly with seed rate and was highest at 6 kg.ha^{-1} in both cropping systems despite the high plant populations. Gelinas and Seguin (2008) noted that seed rate did not affect amaranth grain yield which may be due to self-thinning at high plant density without yield increase. Zimdahl (1980) had observed that higher plant population would mean greater inter-plant competition for growth factors and, hence, lower individual plant performance. The highest seed yields were obtained for the sole and intercropping systems at 6 and 4 kg.ha^{-1} seed rates respectively. Cropping system had no effect on maize grain yield in both years while the decrease as the amaranth seed rate increased was not significant (P=0.05). Makinde *et al*. (2009) had shown that maize growth and yield were not reduced due to intercropping or time of establishment with maize. The decrease in yield relative to sole maize was 7.6% at 2 kg.ha^{-1} and 11.6 at 4 and 6 kg.ha^{-1} seed rates in 2010; 15.6, 16.9 and 21.1% at 2, 4 and 6 kg.ha^{-1} in 2011 implying that amaranth left for a longer period to produce mature inflorescences could effectively compete with maize.

Land equivalent ratio (LER) used to measure biological efficiency of intercropping systems calculated for the maize-leaf amaranth mixture is shown in Table 4. LER exceeded 1.0 for the maize-leaf amaranth intercropping systems and indicate their intrinsic yield advantages over the respective sole crops. LER was highest for amaranth marketable yield obtained by uprooting and repeated cutting at 6 and 4 kg.ha^{-1} seed rates, respectively in 2010 whereas LER was highest at 6kg.ha^{-1} closely followed by 4 kg.ha^{-1} seed rate in 2011. Manga *et al*. (2003) and Olorunnisomo and Ayodele (2009) obtained similar intercropping advantages in maize-grain amaranth planted in alternate rows or 70: 30 proportion. The LER for amaranth seed yield was highest at 4 kg.ha^{-1} amaranth seed rate in the two years. The implication is that seed rates for intercropping advantages would differ depending on the desired economic portion of the leaf amaranth grown as a companion crop to maize.

Conclusion and Recommendation

Maize planted at 75x25 cm (53,330 plants.ha^{-1}) and leaf amaranth drilled in 20 cm rows were grown sole and in mixtures. Intercropping with maize had no significant effect on number of emerged seedlings of leaf amaranth and marketable yields obtained by uprooting and repeated cutting but decreased seed yield of the amaranth. The number of seedlings and marketable yield increased linearly over the 2-6 kg.ha^{-1} amaranth seed rate in sole and intercropping systems. The appropriate amaranth seed rates are 4 and 6 kg.ha^{-1} for optimum marketable yield in sole leaf amaranth and maize-amaranth intercrop, respectively. Intercropped amaranth slightly reduced maize yield as amaranth seed rate increased but the mixtures showed sufficient intercropping advantages as indicated by LER >1.0 and with appropriate recommendations of 6 kg.ha^{-1} seed rate for marketable yield and 4 kg.ha^{-1} for amaranth seed.

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Table 1: Cropping systems and seed rates effects on population of leaf amaranth seedlings in maize-amaranth mixtures

Cropping System	Amaranth Seed Rate (kg.ha-1) 2	4	6	Mean
	x 10^6 Plants.ha^{-1}			
2010 season				
Sole	1.30h	1.90g	2.30g	1.83
Intercropping	1.10h	2.00g	3.30f	2.13
Mean	1.20c	1.95b	2.80a	NS
2011 season				
Sole	0.94h	1.39g	1.66f	1.33b
Intercropping	0.88h	1.44g	1.98e	1.43a
Mean	0.91y	1.42x	1.82w	-

Treatment means and values within a treatment group followed by same letters do not differ significantly (P=0.05) NS= Not significant

Table 2: Effect of cropping system and amaranth seed rate on marketable yield of leaf amaranth

Seed Rate	Uprooting			Repeated Cutting		
(kg.ha^{-1})	Sole	Intercropping	Mean	Sole	Intercropping	Mean
2010 season						
2	14.80f	11.70g	13.25b	8.001	11.70j	9.85ab
4	10.70g	12.20g	11.45c	10.40k	8.601	9.50b
6	15.60f	17.20e	16.40a	10.00k	10.80k	10.40a
Mean	13.70	13.73	NS	9.47	10.37	NS
2011 season						
2	12.58r	10.53s	11.56y	12.29	11.20	11.75
4	14.98pq	13.18qr	14.08x	11.61	12.46	12.04
6	15.76p	15.48p	15.62w	11.45	12.96	12.21
Mean	14.44a	13.06b	-	11.78	12.21	NS

Treatment means and values within a treatment group followed by same letters do not differ significantly (P=0.05) NS= Not significant

Table 3: Amaranth seed yield and maize grain yield as influence by amaranth seed rates and cropping systems

Seed Rate	Amaranth Seed Yield Sole Cropping	Intercropping	Mean	Maize Grain Yield Sole Cropping	Intercropping	Mean
kg.ha^{-1}	MT.ha^{-1}			MT.ha^{-1}		
2010 season						
2	2.60e	1.60f	2.10	5.20j	4.80jk	5.00
4	2.50e	2.60e	2.55	5.20j	4.60k	4.90
6	2.80e	1.90f	2.75	5.20j	4.60k	4.90
Mean	2.63a	2.03b	NS	5.20	4.67	NS
2011 season						
2	1.56	1.28	1.42	4.30	3.71	4.01
4	1.50	1.95	1.73	4.30	3.68	3.99
6	1.71	1.67	1.69	4.30	3.55	3.93
Mean	1.59	1.63	NS	4.30	3.65	NS

Treatment means and values within a treatment group followed by same letters do not differ significantly (P=0.05) NS= Not significant

Table 4: Land Equivalent Ratios (LER) for yield in maize-leaf amaranth intercropping systems

Seed Rate (kg.ha^{-1})	Uprooting	Repeated Cutting	Seed Yield
2010 season			
2	1.71	1.61	1.54
4	2.11	2.09	1.41
6	1.99	1.97	1.56
2011 season			
2	1.69	1.77	1.68
4	1.77	1.92	2.17
6	1.97	1.81	1.81

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