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THE POTENTIAL OF *Andropogon gayanus* Kunth IN THE OXISOL AND ULTISOL SAVANNAS OF TROPICAL AMERICA

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Beef is a staple food in Latin America. About 70% of its beef production is in tropical regions. Tropical America has a higher *per capita* beef cattle population than North America, Western Europe, or Tropical Africa; however, beef production per animal and *per capita* beef consumption are relatively low (CIAT, 1978).

Approximately 51% (850 million ha) of Tropical America is covered by Oxisols or Ultisols. Of this total approximately 300 million ha are covered by savanna vegetation and approximately 550 million ha are covered by forest vegetation. It has been estimated that 70 to 75% of these soils are well-drained (CIAT, 1978; T. Cochrane, personal communication). The principle barrier to beef production in these areas is inadequate year-round forage supply caused by low soil fertility and soil water stress, drought on well-drained soils and flooding or soil saturation on poorly-drained soils. The identification and use of forage species better adapted to the soil and climatic conditions of these areas is one means of increasing beef production.

Andropogon gayanus Kunth, commonly known as Gamba grass or Sadabahar (India), is a large tufted perennial African species of considerable economic importance in West Africa (Bowden, 1964a; de Leeuw and Brinckman, 1974). It has been reported to show promise upon introduction into Australia (Anon., 1950 and 1952; Graham, 1951; Reid and Miller, 1970), India (Chatterjee, 1964), Jamaica (Anon., 1957), Brazil (Otero, 1961; Emrich, 1972), and Colombia (CIAT, 1977 and 1978). In agronomic trials it has been reported to be easily established, highly productive, palatable to livestock, compatible with legumes, and very resistant to drought stress, burning and problem soils (Ademosun, 1974; Whyte, Moir and Cooper, 1959; Bowden, 1963a; Bogdan, 1977). The purpose of this paper is to review the literature concerning its botanical and agronomic characteristics and to determine its potential as a forage grass for the acid, infertile, well-drained soils of Latin America.

BOTANICAL CHARACTERISTICS

Systematics.

Andropogon gayanus Kunth is normally divided into three varieties (Bowden, 1964b):

var. gayanus (var. genuinus Hack.)

Joints and pedicels ciliate along one margin; pedicelled spikelets glabrous; callus beard scanty; awn 1–2 cm long.

var. squamulatus (Hochst.) Stapf.

Joints and pedicels ciliate along both margins; pedicelled spikelets scaberulous and puberulous; callus beard dense, frontal and lateral; awn 2–3 cm long.

var. bisquamulatus (Hochst.) Hack.

Joints and pedicels ciliate on both margins; pedicelled spikelets hairy to villous; callus beard dense, frontal and lateral; awn 2–3 cm long.

Other taxa have been split off from var. bisquamulatus. Bor (cited in Bowden, 1964b) recognizes var. argyrophoeus as a more hairy form with pedicelled spikelets plumosely villous and basal leaves villous. Foster (1962) recognizes var. tridentatus as a largely diploid form with joints and pedicels ciliate on one side and sessile spikelets 6–8 mm long (see Bowden, 1964b).

Foster (1962) has found continuous variation in the degree of leaf hairiness, leaf width, and the presence or absence of hairs on the pedicelled spikelet, a trait used to distinguish var. squamulatus from var. bisquamulatus.

Morphology and Anatomy.

The morphology and anatomy of var. bisquamulatus have been studied in detail by Bowden (1964a). It is a large perennial grass forming, due to short rhizome internodes and intravaginal branching, dense tussocks to 1 m in diameter and producing large inflorescences to 3 m tall. Its morphological and anatomical characteristics are almost entirely panicoid. The embryo, however, possesses two festucoid characters: it has an epiblast and lacks a scutellar cleft.

Var. *squamulatus* and var. *gayanus* have not been studied in detail.

Distribution.

Bowden (1964b) has described the altitudinal, geographical and climatic distribution of *A. gayanus*. In Africa it occurs almost exclusively between the 400 mm and the 1500 mm annual isohyets except when locally favorable soil and topographical conditions permit its growth at lower annual rainfall or when forest clearing practices allow its extension into higher rainfall areas normally dominated by closed forest (Adejuwon, 1974).

Var. *squamulatus* is a moderately vigorous type not exceeding 1.5 m in height and is the most widely distributed of the three varieties. It is found on well-drained soils throught tropical Africa. North of the equator it extends in a wide belt between the Sahara and the equatorial rainforests from Senegal on the west to the Sudan and northern Uganda on the east. South of the equator it is found in the savannas to the east and south of the equatorial rainforests in Zaire and as far south as Mozambique and the Transvaal in South Africa. It occurs up to 2300 and occasionally to 2600 m.

Var. *bisquamulatus* is a large vigorous type often exceeding 2 m in height. It is found on well-drained soils to 2000 m and has a geographical distribution almost identical to that of var. *squamulatus* north of the equator. It does not occur south of the equator. Varieties *squamulatus* and *bisquamulatus* have invaded man-made savanna areas throughout the northern part of the forest zone in Nigeria (Adejuwon, 1974). Var. *bisquamulatus* has been introduced into Colombia, South America and grows vigorously with a bimodal rainfall distribution of over 1800 mm annually and with a single 5 month dry season and 2100 mm annual rainfall.

Var. *gayanus* occurs on seasonally flooded land in West Africa where it forms almost pur stands (Bogdan, 1977; Bowden, 1964b). Th also occurs south of the equatorial rainforests in Zaïre.

Var. *tridentatus* is shorter than var. *bisquamulatus* and occurs in the semidesert parts of the Sahel zone of West Africa (Bogdan, 1977; Foster, 1962).

The varieties *squamulatus*, *bisquamulatus* and *gayanus* occur naturally where the average minimum temperature of the coldest winter month does not fall below 4.4 C (Bowden, 1964b). The species tolerates light frosts (Chatterjee and Singh, 1966).

Varieties *squamulatus* and *bisquamulatus* can withstand up to 9 months of drought, but their most favorable environment appears to be below 1000 m with a dry season of 3 to 5 months and a total rainfall of over 750 mm (Bogdan, 1977; Bowden, 1963a).

Flowering behavior.

Andropogon gayanus, like most members of the Andropogoneae (Evans, 1964), is a short-day plant. Its critical daylength for flowering is between 12 and 14 hr (Tompsett, 1976). Flowering is intensified by shortening daylength from 12 to 8 hr or by exposing older plants to short-day treatments. Flowering is optimum at approximately 25°C, but cool night temperatures (15°C) strongly inhibit flowering. Auxin, gibberellin, abscisic acid, and dimethylaminosuccinamic acid (B9) inhibit flowering under normally inductive conditions. Several growth hormone treatments including combinations of the above fail to stimulate flowering in long days. Whole or partial root removal inhibits flowering suggesting that cytokinin or gibberellin production by the roots (Atkin, Barton and Robinson, 1973) may stimulate flowering.

The maximum flowering response can be induced by short-day exposure of only one expanding leaf —for example by wrapping the leaf with aluminum foil. Young leaves are more sensitive to the photoperiodic stimulus than old leaves. Use of this technique could facilitate breeding since three generations per year can be produced (Tompsett, 1976).

Haggar (1966) reported that at Shika, Nigeria the tillers formed before or during the early part of the rainy season make the greatest contribution to the final seed yield. Very few new tillers are formed after the first two months of the rainy season, and those that are formed fail to flower. With regard to percentage of flowering tillers and inflorescence length, tillers formed before the rainy season behave similarly to those produced at the beginning of the rainy season.

Chatterjee and Singh (1968) reported that in India tiller death continues throughout the year but is greatest after panicle emergence and during the dry season. In general tillers die within the year of their formation and are replaced by new tillers. Tiller number is lowest at flowering and increases to a maximum during the early part of the rainy season (Singh and Chatterjee, 1965).

Flowering occurs for approximately one hour between 600 and 1400 (Foster, 1962). Flowering is acropetal, and each raceme pair takes about 5 days to complete flowering. Both time of day and date of flowering are correlated with the origin of the ecotype. At Shika, Nigeria, the flowers of ecotypes from drier northern Nigeria open earlier in the morning than do those of ecotypes from farther south. These ecotypes also begin flowering as much as 48 days earlier than those from farther south (Foster, 1962). This is probably a photoperiodic response (Tompsett, 1976) and an adaptation to the shorter rainy season in northern Nigeria since each ecotype begins flowering on the date which coincides with the end of the rainy season at its site of collection (Foster, 1962).

Foster (1962) reports that the species produces pollen from a single raceme pair on all five days of its flowering period, but stigmas are only exerted on the first three days. He hypothesizes that the flowering date of the population as a whole will tend to become earlier if climatic conditions allow.

Other studies have examined the structure and function of leaf nectaries (Bowden, 1971), the ligules (Bowden, 1964c), and the triglyceride metabolism of germinating seeds (Williams and Bowden, 1973).

AGRONOMIC CHARACTERISTICS

Andropogon gayanus var. bisquamulatus is more vigorous and aggressive than var. squamulatus (Bowden, 1963a; P.N. de Leeuw, personal communication). In West Africa these two varieties are known for their drought resistance, retention of green foliage well into the dry season, and rapid production of high quality forage at the beginning of the rainy season (Anon., 1942; Bogdan, 1977). The species is well adapted to burning, and careful grazing management, periodic burning, or cutting may be necessary suppress the accumulation of old fibrous material (Bowden, 1963a; Haggar, 1970). In unburned ungrazed A. gayanus pastures litter can constitute more than 50% of the total organic matter during the dry season (Egunjobi, 1974).

In the eastern savannas of Colombia the regrowth of native savanna is greater than that of A. gayanus for the first 4-5 days after burning; however, within 10 days the regrowth of A. gayanus greater. After 6 weeks its regrowth was over twice that of native savanna (997 vs. 419 kg DM ha^{-1}). Lignification of the regrowth appears to be much slower in A. gayanus than in native savanna (M. Sánchez, personal communication).

Var. bisquamulatus is known to aggressively colonize disturbed soil in both fallow fields (P.N. de Leeuw, personal communication) and disturbed native savanna (J.M. Spain, personal communication). In northern Nigeria it is sown in grass fallow and is known to be useful in building soil fertility (Bowden, 1963a). Its beneficial effect on subsequent crops is probably due more to improve soil fertility than to a long-lasting improvement of soil physical properties (Wilkinson, 1975).

Andropogon gayanus is adapted to a range of soil types including rich alluvial soils (Barrault, 1973), serpentine soils (Wild, 1974a and 1974b), Oxisols and Ultisols (CIAT, 1977), and well drained sandy clays of medium to high fertility (Bowden, 1963a).

Establishment.

Andropogon gayanus may be established either from crown splits or seed. Crown splits are often used in experimental work to quickly establish a uniform stand. Since the species is allogamious and plants vary morphologically splits should be taken from a number of plants and randomized within a plot. Where seed quality or other factors prohibit mechanized planting of seed low density planting (1000 plants ha^{-1} or less) of crown splits appear promising. Even when the land is prepared and splits are planted late in the wet season, seed production may be sufficient to insure a good stand the following rainy season (J. M. Spain, personal communication).

Seed may be sown broadcast or in rows. Bowden (1963a) recommends sowing 1.2 to 2.5 cm deep on well prepared seedbed. Sowing rates depend largely on seed fertility. Bogdan (1977) recommends sowing at least 45 kg uncleaned seed ha^{-1} if quality is unknown. A total of 2 kg pure germinating seed ha^{-1} is probably sufficient (J.E. Ferguson, personal communication).

Since *A. gayanus*, like many perennial grasses, produces little forage during the wet season in which it is sown, it can be sown with annual companion crops to increase the economic yield during the first year. In Nigeria (Haggar, 1969), maize and soybeans are more suitable companion crops than mucuna (*Stizolobium* sp.), a trailing legume, or the annual grass *Pennisetum pedicellatum*. The latter are too competitive. All companion crops significantly reduce weed competition, and their early harvest improves establishment of *A. gayanus*. Dry matter yields in the first year are higher when the grass is sown broadcast, but establishment in rows shows a slight advantage after the first year.

Dry Matter Yield and Water Use Efficiency.

The reported dry matter yields for *A. gayanus* range from less than 3 (Haggar, 1966) to over 17 tons DM ha^{-1} yr^{-1} (CIAT, 1978). In mature stands important yield-determining factors appear to be previous grazing management (Haggar, 1975), fertility (Haggar, 1966 and 1975; Barrault, 1973), and rainf ll (Barrault, 1973; Haggar, 1975; Anon. 1978).

Bowden (1963a) reviewed DM yields obtained in 5 African trials. In these trials *A. gayanus* was always among the three highest yielding species. Its yield was roughly comparable to that of *Panicum r aximum*. It outyielded *P. maximum* in two trials, yielded less than *P. maximum* in two trials, and produced equivalent yields in one trial.

At 23° North Latitute in India *A. gayanus* and *Brachiaria brizantha* had equal annual DM yields (11.6 tons ha^{-1}) and outyielded the 10 other grasses in the trial. Interestingly, *A. gayanus* had the highest DM yield (1.2 tons ha^{-1}) during the 7-month dry season (Singh and Chatterjee, 1965). On an annual basis it produced 9 to 10 kg DM ha^{-1} mm^{-1} rainfall.

In an analysis of several experiments in Nigeria and Cameroon, *A. gayanus* grown at near optimum fertility yielded approximately 8 to 12 kg DM ha^{-1} mm^{-1} rainfall in 4 to 5-month rainy seasons (Barrault, 1973; Haggar, 1975). In Brazil Emrich (1972) reported fresh weight yields which, when calculated on the basis of 25% to 30% DM (see

Barrault, 1973), are equivalent to 9 to 11 kg DM ha^{-1} mm^{-1} total rainfall during two 6-month rainy seasons.

In Colombia (CIAT, 1978; B. Grof, personal communication) *A. gayanus* grown in association with legumes on an infertile Ultisol with 90 kg P_2O_5 ha^{-1} yielded approximately 11 kg DM ha^{-1} mm^{-1} rainfall. The companion legumes yielded an average of 3.4 kg DM ha^{-1} mm^{-1} rainfall. In comparison, *Hyparrhenia rufa* and the same associated legumes yielded 9 and 4.5 kg DM ha^{-1} mm^{-1} rainfall, respectively. These high values of water use efficiency under relative low fertility may be the result of low water loss due to deep drainage and runoff because of the bimodal distribution of rainfall.

Haggar (1970) reported maximum crop growth rates in lightly fertilized *A. gayanus* pastures of slightly over 32 kg DM ha^{-1} day^{-1} for at least a month prior to stem elongation.

The ability of *A. gayanus* to remain green throughout much of the dry season then provide an "early bite" at the beginning of the rainy season is one of its most important agronomic characteristics (Bowden, 1963a; Bogdan, 1977). Nevertheless, only one study has been conducted on its root system (Bowden, 1963b). *Andropogon gayanus* var. *bisquamulatus* was grown as spaced plants at Kampala, Uganda. Three morphological classes of roots were identified. Fibrous roots are profusely branched distally, usually less than 0.5 mm diameter, and extend laterally over a meter from the plant. Cord roots are about 2 mm in diameter, are sparsely branched, make an angle of 30° to 40° with the soil surface, and are seldom more than 0.5 m in length. Vertical roots resemble fibrous roots except that they are sparsely branched and extend vertically for more than 80 cm. The total root system consisted of 50% fibrous roots, 40% cord roots, and 10% vertical roots (by weight).

During the dry season on a deep Oxisol in Carimagua, Colombia *A. gayanus*, like *Brachiaria decumbens*, continued to extract water from the deeper layers of the soil profile longer than *P. maximum* (J.M. Spain, personal communication). During the dry season it produced slightly greater DM yields than *B. decumbens* (P. Sánchez, personal communication). Two months into the dry season both its early morning and mid-afternoon leaf water potentials were similar to these of *B. decumbens* and higher (less negative) than those of *P. maximum* and *H. rufa* (the author, unpublished data). This probably indicates a better developed root system than those of *P. maximum* and *H. rufa*.

In Carimagua row spacing and cutting frequency are major factors affecting the relative yields of *A. gayanus* and *B. decumbens* in the wet season. With an 8-week cutting interval and 1.0-meter row spacing *B. decumbens* produced almost twice a much DM as *A. gayanus* (P. Sánchez, personal communication); however, with 0.5-meter row spacing and only three cuts per year *A. gayanus* yielded slightly more DM than *B. decumbens* or *P. maximum* (F. Müller, personal communication). These data agree with those of Barrault (1973) which indicate that lower frequency of cutting favors total DM accumulation in *A. gayanus*. Light interception is probably limits crop growth rate under frequent cutting and is a major factor in yield depression under frequent cutting and/or wide row spacing. From these data it appears that the competitive advantage of *A. gayanus* can be readily manipulated by grazing management.

Quality.

Values of percentage crude protein (CP) and digestibility vary within plants as a function of plant part, age and soil fertility. Table 1 summarizes data from a number of sources for *A. gayanus*. From Table 1 it is evident that *A. gayanus* is a grass of medium to low nutritive value.

Miller and Rains (1963) found that of 8 species studied in northern Nigeria *A. gayanus* was the best agronomically, but its percentage digestible crude protein was comparable to that of native savanna species. Where comparisons were made between grasses on high-fertility soils, *P. maximum* and *Pennisetum purpureum* were superior to *A. gayanus* in digestibility and crude protein content.

Reid *et al.* (1973) measured the *in vitro* dry matter digestibility (IVDMD) of a number of grasses throughout a 16-week period during the rainy season in Uganda. The digestibility of unclipped *A. gayanus* forage dropped from approximately 68% at the beginning of the rainy season at a rate of about 1.5% per week. Its digestibility was generally below that of a number of *Brachiaria* species and *Digitaria decumbens*. It was about equal to that of *Cynodon dactylon* and *P. maximum* var. *Makueni*, and it was higher than that of *H. rufa*.

Haggar and Ahmed (1970) reported on 27 sheep feeding trials in which freshly cut *A. gayanus* hay was fed during the wet season at Shika, Nigeria. In each year IVDMD and voluntary intake were highest during the first part of the growing season and declined with advancing maturity of the plants. There were small increases in voluntary dry matter intake at the time of panicle emergence, but further decreases followed. The IVDMD of elongating stems was as high as that of leaves. Voluntary feed intake was related to IVDMD (r=0.40) and CP (r=0.82). Percentage crude protein was related to percentage digestible crude protein (r=0.88). Percentage crude protein was concluded to be a useful criterion for predicting nutritive values.

Haggar (1970) studied yield, yield components and quality parameters in unfertilized and lightly fertilized A. gayanus var. bisquamulatus swards growing uninterruptedly (ungrazed and uncut) during both wet and dry seasons in Shika, Nigeria. During the 1964 wet season standing crop DM on unfertilized plots increased sigmoidally to 3.9 tons ha^{-1}. During the following dry season the standing crop never dropped below 2.8 tons ha^{-1}; however, CP dropped from over 6% at the beginning of the wet season, to approximately 4% during the period of rapid growth in the middle of the wet season, to less than 1.5% in the fourth month of the dry season. During the 1967 wet season analysis of yield components showed that the percentage of green leaf in the total dry matter ranged from about 60% before stem elongation to about 25% at flowering. This was accompained by a drop in the CP content of the entire plant from about 4.5% during the rainy season to 3.0% in the second month of the dry season. During the same period the CP of the green leaf component never dropped below 5.5%.

Bowden (1963a) cites reports that in a 2-year, 12-variety palatability trial in Nigeria A. gayanus ranked highest in palatability followed by Panicum coloratum, P. maximum and P. purpureum.

In a preference trial in Ghana cattle, sheep, and goats grazed a total of 12 major grass species. All livestock showed preference for

A. gayanus, P. maximum, Setaria sphacelata and B. decumbens, (Tetteh, 1974).

The importance of selective consumption of low quality of A. gayanus hay to intake and digestibility in sheep was demonstrated by Haggar and Ahmed (1970) and Haggar (1972). Restricting the amount of feed on offer reduced dry matter digestibility, presumably because the sheep were forced to consume more of the undigestible stem portions. Reducing selective consumption by chopping the hay resulted in lower voluntary intake. Zemmelink, Haggar and Davies (1972) found that cattle select strongly for leafy material when fed low quality A. gayanus hay.

The data indicate that on infertile soils mature pure stands of A. gayanus are unsuitable for use as hay (Haggar, 1972; Miller and Rains, 1963). Only by selective grazing of green leaf material can animals obtain a diet with a reasonable crude protein content (Haggar, 1970; Haggar and Ahmed, 1970 and 1971; Milford and Minson, 1965). The situation can be improved considerably through increased soil fertility (Barrault, 1973; Sen and Mabey, 1966), management aimed at producing continual young growth (Rains and Foster, 1958; Barrault, 1973), and inclusion of a leguminous associate or supplement (CIAT, 1978; Haggar, 1972).

Response to Fertility.

The response of crops to fertilizer N is difficult to compare between sites and between years because of differences in the nitrogen-supplying power of different soils and differences in drought stress which cause variation in the efficiency with which N is utilized by the plant. Figure 1 shows the N response curves found by several authors for *A. gayanus*. Large differences are evident in both the native N-supplying power of the soils (reflected in yield without addition of fertilizer N) and the efficiency of N use (the initial slope of the N response curves). 1/.

Figure 2 shows the effect of rainfall on the response of DM yield to fertilizer N application in the few experiments in which rainfall and the response of dry matter yield to N fertilization were reported. From Figure 2 it appears that approximately 600 mm annual rainfall is necessary before significant response to fertilizer N can be expected. After the first 600 mm rainfall each 100 mm of rainfall (to approximately 1250 mm) increased DM production per hectare by approximately 8 kg ha^{-1} yr^{-1} kg^{-1} fertilizer N (up to approximately 100 kg N ha^{-1} yr^{-1}).

In Shika, Nigeria (Haggar, 1975) the beginning of the rainy season was the most efficient time to apply N. "Nitro-chalk" and calcium nitrate were more efficient sources of N than were urea, sodium nitrate, or ammonium sulfate.

The response of yield to P fertilization was compared in *A. gayanus*, *P. maximum*, *B. decumbens* and *H. rufa* on a highly infertile Oxisol at Carimagua, Colombia. All four varieties responded up to 400 kg P_2O_5 ha^{-1}. Without addition of fertilizer P, the yields of *A. gayanus*, *B. decumbens*, *H. rufa* and *P. maximum* were 35%, 20%, 10% and 0%, respectively, of the maximum. At 50 kg $P_2O_5ha^{-1}$, the percent of maximum yield of the four grasses were: *A. gayanus*, 55%;

1/ Initial N response evaluated by the "linear response and plateau" method (Waugh, *et al.*, 1975).

B. decumbens, 60%; P. maximum, 38% and H. rufa, 20%. In the same trial A. gayanus responded less than the other three varieties to fertilizer Mg. All varieties responded to S (J.M. Spain, personal communication; CIAT, 1978).

The low external P requirement of A. gayanus was confirmed in pot trials where the critical soil test level was determined by the Cate-Nelson method to be about 5.2 ppm (Available Bray II-P) (F. Müller, personal communication; CIAT, 1978).

The response of A. gayanus to lime on a very acid Oxisol at Carimagua, Colombia, was comparable to that of other aluminium-tolerant species such as Brachiaria humidicola and Brachiaria radicans. Its tolerance was slightly better than that of B. decumbens, P. maximum, B. mutica and B. decumbens. It was much more tolerant than a Cynodon hybrid, H. rufa, and Axonopus scoparius (J.M. Spain, personal communication; CIAT, 1978). In Ghana, A. gayanus did not respond to lime applications which increased the yields of Cenchrus ciliaris and Tripsacum laxum by 10 to 12% (Kannegieter, 1966).

Compatibility with legumes.

Work in Nigeria (Onayinka, 1973; Adegbola and Onayinka, 1966) has shown that A. gayanus is compatible with both trailing (Centrosema sp.) and non-trailing (Stylosanthes guianensis) legumes. The same compatibility has been demonstrated in both clipping and grazing trials in Colombia (CIAT, 1978; B. Grof, personal communication). It has been reported to mix successfully with Clitoria ternata in Northern Australia (Whyte, et al. 1959).

In Ghana from September 1969 to November 1970 A. gayanus produced more dry matter than Digitaria decumbens in pure stand

(37 vs. 17 t/ha), in association with Centrosema pubescens (30 vs. 29 t/ha), and in association with Desmodium leiocarpum (34 vs. 20 t/ha) (Tetteh, 1972).

Animal Production.

Very few data are available concerning animal performance on *A. gayanus* pastures. de Leeuw (1971) reports that on cleared but otherwise unimproved Northern Guinea Zone savannas the maximum yields which could be expected even with moderate supplementary feeding of concentrates is 28 kg live weight ha^{-1} yr^{-1}. In the experiments reviewed by de Leeuw (1971) the best stocking rates on native savannah during the wet season were 0.62 animals ha^{-1}, which gave a mean rate of live weight gain over two wet seasons of 0.17 kg $animal^{-1}$ day^{-1} and a total live weight gain of 16 kg ha^{-1} over a mean of 142 days. In another trial on native savanna the live weight gain at 0.62 head ha^{-1} was about 35 kg ha^{-1} during the wet season (203 days) and −14 kg ha^{-1} during the dry season (140 days). In comparison, live weight gains on semi-natural unfertilized *A. gayanus* grassland over a 3-year period during the wet season were 0.56 kg ha^{-1} day^{-1} at a stocking rate of 2.0 animals ha^{-1} and 0.49 kg ha^{-1} day^{-1} at 1.0 animals ha^{-1}. Total wet season live weight gains in this trial were 84 to 96 kg ha^{-1}.

Another management trial was conducted during the wet season on natural savanna dominated (66%) by *A. gayanus* in Western Nigeria. Application of a total of 112 kg N ha^{-1} increased DM production three fold over the unfertilized control. Live weight gains were 0.39 and 0.77 kg $animal^{-1}$ day^{-1} on unfertilized and fertilized treatments, respectively; and during the second grazing, N fertilization doubled intake of available DM, from 33.5% to 67%. Live weight gains ranged from 116 kg ha^{-1} yr^{-1} without fertilizer N to 250 kg ha^{-1} yr^{-1} with 112 kg N ha^{-1} yr^{-1} (Adegbola, Onayinka and Eweje, 1968).

<u>Seed Production.</u>

Bogdan (1977) reported that yields of uncleaned seed range from 20 to 100 kg ha^{-1} yr^{-1}. He reported that annual seed yields of up to 90 kg ha^{-1} yr^{-1} were obtained in India and Brazil. In the Indian trial the uncleaned seed contained only 5 to 10% caryopses. Bowden (1963a) reported that caryopses content ranged from less than 1% to more than 60%. Germination of caryopses varied only slightly, from 60 to 80%. Bowden (1963a) reported that 2.2 kg ha^{-1} of pure germinating seed is sufficient for establishment, but since seed purity is so variable a minimum rate of 45 kg ha^{-1} of uncleaned seed is recommended.

In Shika, Nigeria the number of flowering tillers was increased three to four-fold by grazing only once, early in the rainy season, rather than three times (Haggar, 1966). On these soils application of up to 67 kg P_2O_5 ha^{-1} had little effect on dry matter yield or seed production. Application of 168 kg N ha^{-1} increased the number of flowering inflorescences approximately two to three-fold. Application of 224 kg N ha^{-1} increased dry matter production from 2.4 to 7.0 tons ha^{-1}, increased inflorescence height from 1.7 to 2.3 m, increased the number of inflorescences from 13 to 36 m^{-2}, increased inflorescence length from 46 to 63 cm, and increased unthreshed seed yields from 25 to 75 kg ha^{-1}. Delay of harvesting until after the rachis tips began to abscise caused severe reduction in seed yield. A 16-day delay in harvesting caused an 84% reduction in seed yield. In this experiment no estimate was made of purity nor germination in the various treatments. Bogdan (1977) reported that germination declines from 80% to 50% in the first year, to 30% in the third year and to zero in 4 to 6-year-old seed.

In Colombia yields of graded seed of 40% purity has varied from 30 to 300 kg ha^{-1} with a mean graded seed yield of 120 kg ha^{-1}. Germination of untreated pure seed has been as high as 65% at 9 months (J.E. Ferguson, personal communication). These yields are considerably better than those reported elsewhere and is probably indicative of the importance of climate in seed production.

Yields of 200 kg/ha of graded seeing testing 40% international purity and 50% germination (i.e. 20% Pure Live Seed (PLS) content), would allow seeding rates of 10 kg ha^{-1} of such seed (providing 2 kg ha^{-1} of PLS). Thus, a multiplication rate of approximately 20 (20 ha seeded for each ha harvested) is feasible.

CONCLUSIONS

Andropogon gayanus Kunth is a large tufted grass species that is highly productive, moderately nutritious in pure stand without N fertilization, and highly palatable to all classes of livestock. It is easily established and is easily eliminated by ploughing. It is very tolerant of problem soils, including Oxisols and Ultisols which are low in P and have high levels of Al saturation. It is resistant to burning and drought stress and is known for its production of green forage throughout the dry season and its rapid recuperation after burning and upon resumption of the rainy season. It appears to be best adapted to monsoonal climates at elevations below 2000 m with dry seasons of 3 to 5 (or more) months and annual rainfall above 750 mm. Under moderate to high fertility annual DM production ranges from 9 to 11 kg DM ha^{-1} mm^{-1} rainfall. It is reported to associate well with a number of legumes, and the few available data indicate that animal gains on either pure stands or on mixtures with legumes are far superior to those on native pasture.

Seed production varies with location, but a ratio of 20 ha planted per ha harvested seems possible to attain. In addition, *A. gayanus* adapts well to companion crops, and good possibilities exist for the development of very low density, minimum input planting techniques which take advantage of self-sown seed.

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Table 1. Contents of crude protein and digestibility coefficients for *Andropogon gayanus* from various sources [1]

Reference	Crude protein [2] (%)	Dry Matter Digestibility (%)	Tissue	Remarks
Haggar and	9.2-6.6 (7.9) [3]	66.0-53.2 (58.1) [3], [4]	unexpanded lamina (1)	No N fertilization,
Ahmad, 1971	7.7-6.1 (7.0)	63.5-51.2 (54.5)	expanded lamina (2)	samples of uncut
	5.4-4.5 (4.9)	60.9-46.5 (52.1)	partly brown lamina (3)	wet season growth
	3.4-2.1 (2.4)	49.5-28.3 (37.7)	brown lamina (4)	taken over a 7-wk
	6.6-3.1 (4.7)	64.1-42.6 (55.1)	stem below (1)	period in the second
	3.5-2.2 (3.1)	65.9-45.5 (55.2)	stem below (2)	half of the rainy
	2.4-1.5 (2.0)	60.5-37.4 (49.9)	stem below (3)	season, Zaria,
	1.5-1.1 (1.3)	53.6-32.5 (43.2)	stem below (4)	Nigeria
Miller and	6.5	61.6 (in sheep) [5]	75-100 cm, cut at 25 cm	No N fertilization,
Rains, 1963	4.3	52.4 (in sheep)	100-125 cm, cut at 25 cm	uncut first growth
	3.8	54.8 (in cattle)	75-100 cm, cut at 12-18 cm	of wet season
	4.1	54.0 (in cattle)	100-125 cm, cut at 12-15 cm	
	6.1	53.6 (in cattle)	25-50 cm, cut at 7-10 cm	
Haggar, 1975	7.0-5.4 (6.2) [3]		4 to 6 week	0 kg N ha^{-1} yr^{-1}
	7.1-5.5 (6.4)		old regrowth	28 "
	7.1-5.6 (6.2)			56 "
	8.1-5.7 (6.9)			112 "
	9.3-6.9 (7.9)			224 "
	11.3-8.5 (9.6)			448 "
	12.6-8.9 (10.4)			896 "

1/ Similar results were reported by Barrault (1973), Haggar (1970), Haggar and Ahmad (1970), Boudet (1970), Anon. (1978), Oyenuga (1957) Reid et al. (1973), and Sen and Mabey (1965).

2/ % N x 6.25

3/ range with mean in brackets

4/ *in vitro* dry matter digestibility

5/ *in vivo* dry matter digestibility

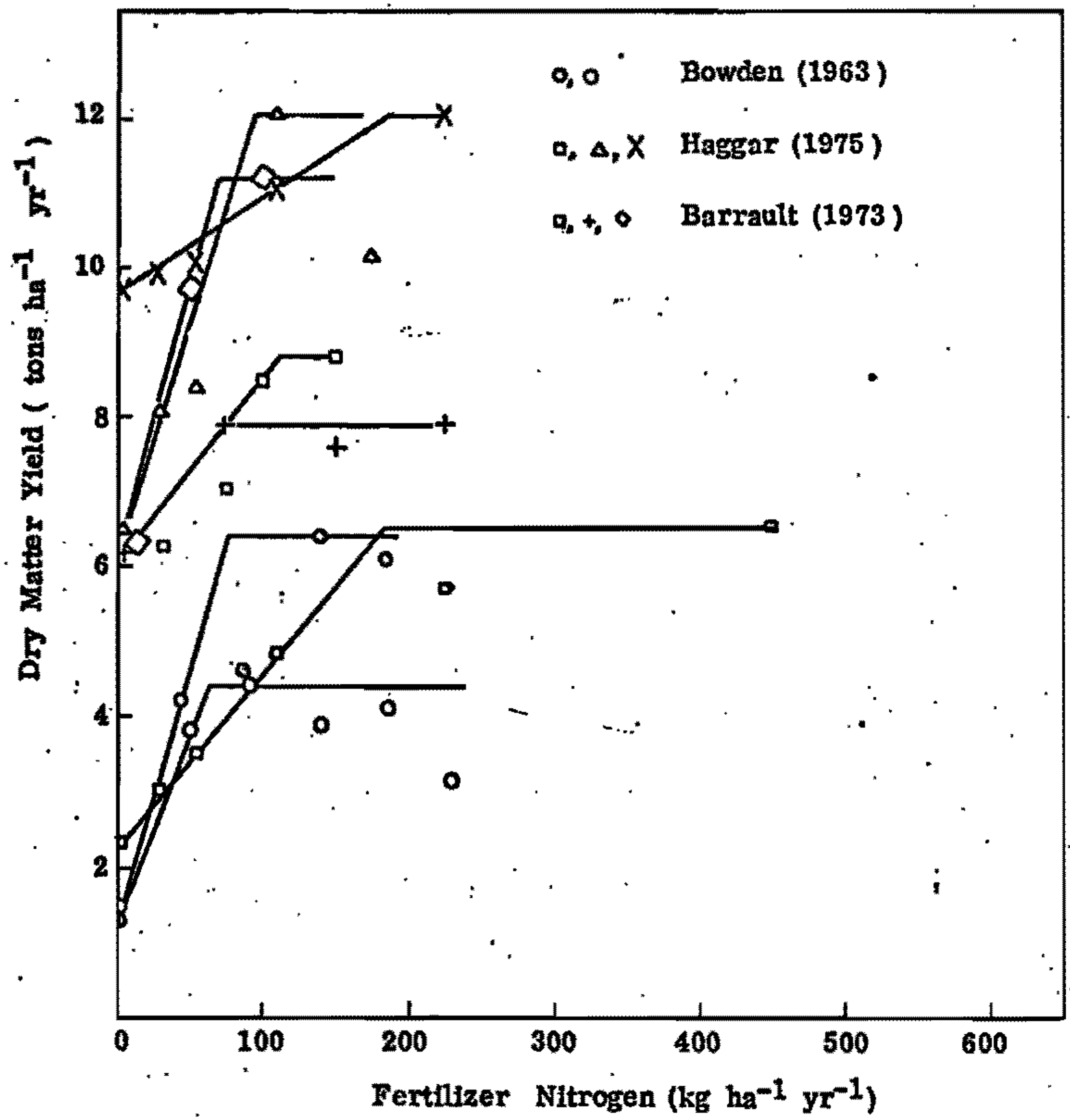

Fig. 1. Response of dry matter yield to fertilizer nitrogen.

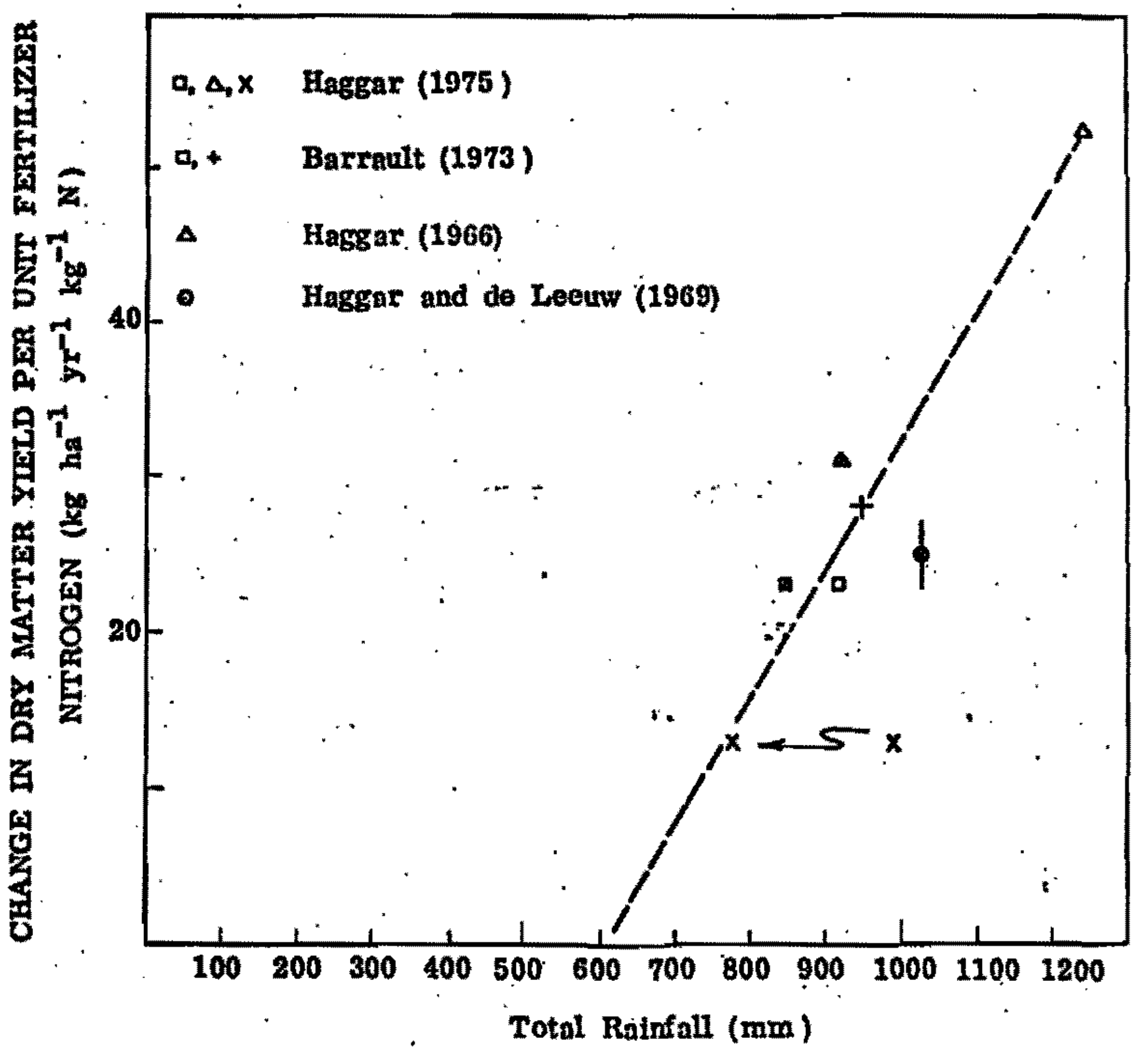

Fig. 2. Effect of rainfall on response of dry matter yield to fertilizer nitrogen. Rainfall corresponding to point (x) has been corrected for abnormally high, ineffective rainfall at the beginning of the rainy season.