Management of Navua sedge (*Cyperus aromaticus*): a role of competition using two pasture species

Boyang Shi [1], Mogomotsi Moilwa [2], Olusegun Osunkoya [1], Kunjithapatham Dhileepan [1] and Steve Adkins [2]
[1] Biosecurity Queensland, Department of Agriculture and Fisheries, Ecosciences Precinct, Dutton Park 4102, Queensland, Australia
[2] School of Agriculture and Food Science, The University of Queensland, Gatton, Queensland, Australia
(Boyang.Shi@daf.qld.gov.au)

Summary Navua sedge (*Cyperus aromaticus* (Ridley) Mattf. & Kük.), is a grass-like perennial weed and is native to equatorial Africa and islands in the Indian Ocean, off the coast of southeast Africa. It was accidentally introduced to Northern Queensland, Australia where it has invaded rangelands and cropping [e.g. sugarcane (*Saccharum officinarum* L.)] areas. Currently, the weed is causing a significant loss to agricultural productivity by smothering pasture, crops, and native plants due to its fast growth rate as well as the absence of sustainable weed control methods. Therefore, it is essential to find a weed control method which can suppress Navua sedge growth to prevent further spread and to control the weed's invasiveness. The hypothesis that vigorously growing grasses can outcompete and suppress the growth of this invasive weed was tested.

A replacement series competition study using five density ratios, at two soil moisture levels of 50 and 100% of field capacity, was established to determine the intraspecific and interspecific competition effect of two fodder grass; Rhodes grass (*Chloris gayana* Kunth) and humidicola (*Brachiaria humidicola* (Rendle) Schweick). on the growth of Navua sedge. At all density ratios and for all three species, there were minimal growth differences in response to soil moisture level. Navua sedge managed to produce more tillers and leaves under all moisture levels as well as at all intraspecific and interspecific competition levels than Rhodes grass and humidicola. However, Rhodes grass produced 4.2 times more biomass in mixtures with Navua sedge than when with humidicola. The results indicate that Rhodes grass had a greater competitive ability than Navua sedge or humidicola, and hence a good candidate to compete with Navua sedge in the field.

Keywords Navua sedge, competition, pasture species, invasive, management.

INTRODUCTION

Navua sedge, *Cyperus aromaticus* (Ridley) Mattf. & Kük. (Cyperaceae), is having a massive impact on the farming communities in Northern Queensland, Australia (Shi et al. 2021). The weed was first detected in Cairns, Northern Queensland, Australia in 1979, where it is now the dominant weed in sugarcane crops and pasture lands. Navua sedge is causing significant losses by strongly out-competing and smothering many tropical pasture species (Vitelli et al. 2010; Vogler et al. 2015). Currently, the control of Navua sedge is restricted to physical, mechanical and chemical control methods, which are not sustainable as they bring only a temporary solution and could also cause potential adverse impacts to the environment. Moreover, the only registered herbicide, Sempra® (halosulfuron-methyl) is not effective in controlling the subterranean rhizomes of Navua sedge (Vogler et al. 2015; Vitelli et al. 2010). A biological control project was initiated in 2017 to prospect for natural enemies of Navua sedge in equatorial Africa and several fungal pathogens were identified. Host specificity testing of promising smut fungus (*Cintractia kyllingae* J. Kruse and R.G. Shivas) and rust (*Uredo kyllingae-erecta* J.M. Yen) are in progress at CABI-UK (Dhileepan et al. 2022).

These observations have brought attention to the search for additional approaches that can assist in the integrated weed management of Navua sedge by reducing seed production and depletion of the soil seedbank. The use of vigorous and competitive fodder plant to suppress the growth of Navua sedge can complement other management approaches. Rhodes grass (*Chloris gayana*) and humidicola (*Brachiaria humidicola*) were selected for a competition experiment with Navua sedge as they are two widely used pasture species with higher growth performance and fodder characteristics in the north Queensland wet tropics. The aim is to explore the competitive effect of these two fodder grasses on the growth performance of Navua sedge using a replacement ratio approach.

MATERIALS AND METHODS

Test species and seedling production Seeds of humidicola (*Brachiaria humidicola*) and Rhodes grass (*Chloris gayana*) were obtained from Heritage Seeds Pty. Ltd. Seed of Navua sedge was collected from South Johnstone, northern Queensland. Seedlings were raised in seedling trays (350 × 295

mm) filled with a sterilized potting mix consisting composted bark (0–12 mm), coco peat, organic minerals, and hydroPlex wetter to boost water holding capacity to up to 50% (Centenary Landscaping (2018). Each species was germinated into 10 trays placed inside a growth cabinet under illuminated conditions with a 14/10-hour photoperiod and a matching 27/22 ± 5ºC (day/night) thermoperiod. Irrigation of seedlings was conducted twice a day. Fertiliser foliar spray was applied on a weekly basis in the last 2 weeks of seedling production stage.

Replacement series Approximately equal size and healthy seedlings of ca. 7 days old were transplanted into 25 cm diameter plastic pots filled with black Vertosol soil (60% clay, pH 7.3) obtained from a field at The University of Queensland Research Station, Gatton, Australia. Transplanting was conducted following a replacement series of five ratios of 4:0, 3:1, 2:2, 1:3 and 0:4 of each species in combination with Navua sedge. In this way, a population of four seedlings per pot was maintained, whereas the proportion of each species in each pot were varied.

In each pot, the seedlings were equally spaced 5 cm apart to allow unbiassed competition. Each replacement ratio had five replicates, resulting 25 pots and 100 seedlings per each species per ratio proportion. The 50 pots were further imposed with two moisture levels of 100% and 50% water field capacity. All the pots were labelled according to the water field capacity level, density ratio, type of species and replicate number. Pots were maintained on a bench in a glasshouse under 27/22 ± 5ºC (day/night) thermoperiod with 60% humidity. Randomisation of the pots were conducted on a weekly basis to allow equal experience of temperature, light and humidity among the pots and seedlings. The pots and their treatments were also randomly distributed within each bench. All transplanted seedling mortalities in the first 7 days of the trial were replaced with seedlings of the same size. The trial ran for 8 weeks with daily monitoring to maintain the water field capacity.

Various plant growth parameters, including plant height, number of tillers, number of inflorescences and biomass, were measured at the termination stage.

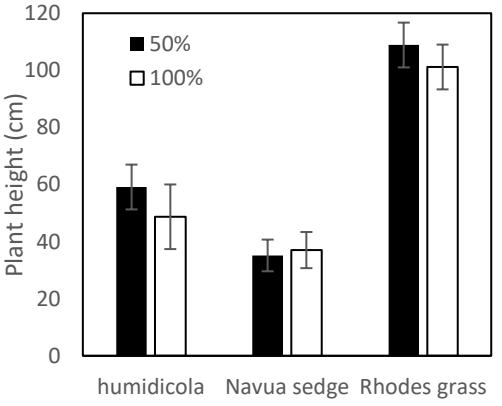
Data analysis The relative yield (RY) was calculated using the following equations which describes the relative biomass of each species in interspecific competition as a percentage of its intraspecific biomass under the same growing conditions (Prince et al. 2018): $RY_x = X_{inter}/X_{intra}$, whereby RY_x is the relative yield of a plant x, X_{inter} is the biomass of x growing in mixtures and X_{intra} is the biomass of x growing alone (monoculture). A three-way analysis of variance in SPSS (IBM version 25) was used to perform the statistical analysis, with species (three levels), moisture condition (two levels) and competition type (two levels) as the main factors. The 4:0 or 0:4 ratios are measured of intraspecific competition, while 3:1, 2:2 and 1:3 ratios measure intensity of interspecific competition. The comparisons of means between group effects were performed by using the Tukey's test and a p-value smaller than 0.05 was considered significantly different.

RESULTS

Overall observations Main effects of species, competition type and moisture levels were significant. For all treatments, there was no significant interaction effect of moisture and competition for the height, but with marginal effect on number of tillers, the number of Navua sedge inflorescences and biomass (Table 1).

Plant height Rhodes grass excelled in plant height attainment. There was significant difference in plant height for all species with Navua sedge being shortest (Figure 1, Table 1).

Figure 1. Plant height of Navua sedge (mean ± SE) and two pasture species (humidicola and Rhodes grass) under two moisture capacity levels (50 and 100%).



Tiller production At all replacement ratios, Navua sedge produced greatest number of tillers, followed by humidicola and Rhodes grass (Figure 2, Table 1).

Table 1. Summary tests of ANOVA for the effects of interspecific or intraspecific competition for Navua sedge, humidicola and Rhodes grass under intra/interspecific competition and with two soil moisture capacity levels. Note that the number of inflorescences is only recorded for Navua sedge.
* $P \leq 0.05$; ** $P \leq 0.02$; *** $P \leq 0.00$

Factor	df	*F* ratio and probability			
		Tiller number	Plant height	Inflorescences number	Biomass gained
Species (S)	2	239 ***	1390 ***	556 ***	112 ***
Competition (C)	1	0.78	2.38	13.8 ***	12.35 ***
Moisture (M)	1	4.18 *	0.48	1.13	4.68 *
S × C	2	3.72 *	3.47 *	12.5 ***	30.04 ***
S × M	2	0.48	37.85 ***	0.68	5.47 **
C × M	1	0.5	0.5	0.27	2.89
S × C × M	2	0.18	1.63	1.85	1.59

Figure 2. Number of tillers (mean ± SE) produced by Navua sedge and two pasture species (humidicola and Rhodes grass) under two moisture capacity levels (50 and 100%).

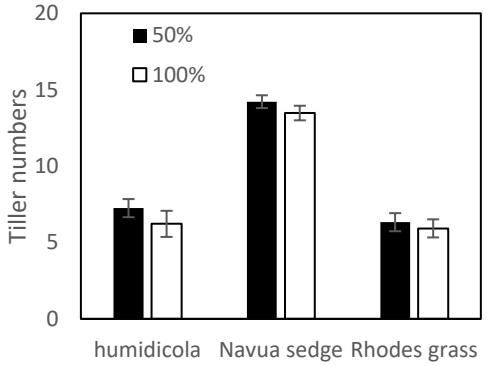
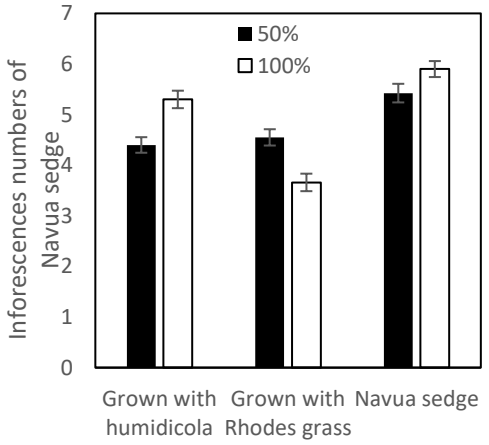


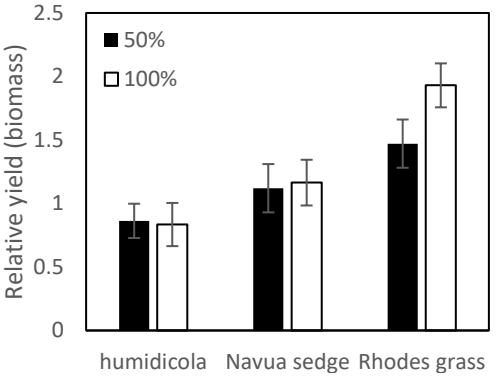
Figure 3. Inflorescence numbers (mean ± SE) of Navua sedge when grown with humidicola as compared to Rhodes grass under two moisture capacity levels (50 and 100%).



Inflorescence production During the time of the study, only Navua sedge produced inflorescences due to short duration of the study. More inflorescences of Navua sedge were produced in the monoculture (intraspecific competition) than when mixed with other species (interspecific competition). Additionally, similar number of inflorescences of Navua sedge were produced when grown with humidicola or with Rhodes grass (Figure 3).

Biomass production Rhodes grass produced more biomass than both Navua sedge and humidicola under both high and low moisture capacity. Interestingly, Rhodes grass produced more biomass under interspecific combinations than when it was growing in the monoculture (Figure 4 and 5).

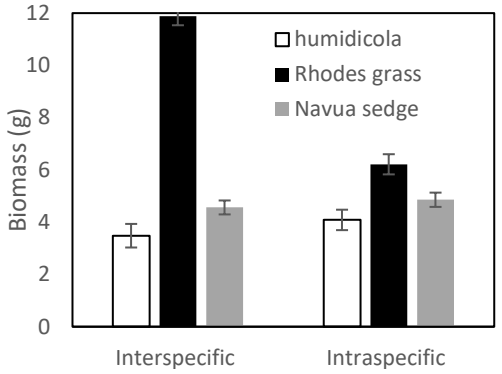
Figure 4. Relative yield (mean ± SE) of total biomass for humidicola, Navua sedge and Rhodes grass under two moisture capacity levels (50 and 100%).



DISCUSSION

A mixture plant growth competition study should examine the plant responses to competition as well as the components of the plant interactions (Radosevich 1987). A replacement series method was selected to find the competitive effect of humidicola and Rhodes grass on the growth of Navua sedge. The approach was chosen in this study

Figure 5. Total biomass of humidicola (white), Rhodes grass (black) and Navua sedge (grey) under interspecific and intraspecific competition.



because it has the ability to avoid criticism when compared to additive method which inadequately accounts for the influence of density and species proportion on the outcome of competition (Radosevich 1987).

Height is a competitive advantage character where taller growing plants can shade the shorter species and inhibit them from accessing light energy resource (Falster and Westoby 2003). Light is a significant resource for plant competition which can result in a reduction of reproduction and growth rate. Both humidicola and Rhodes grass were able to grow taller than Navua sedge which in turn could reduce the biomass of Navua sedge by shading/inhibiting access to sunlight. The initiation and development of tillers in a plant is a basic unit of production which is also correlated to the vegetative period of a species and it affects the plant height as well as the structure of a plant (Anwar et al. 2012). Seavers and Wright (1999) stated that the tillering capacity of a plant is a critical element that can influence the competitiveness of a species to establish in an area, indicating that large tiller number production of Navua sedge will help its invasiveness. The duration of the trial was too short to reach the maturity stage of reproduction of all species, hence the competition experiment may not be robust enough to give a conclusive outcome of winners and losers. Further field trials to validate the results are needed. Nonetheless, the growth behavior of Rhodes grass indicates increasing yield under interspecific competition compared to growth in intraspecific competition. Thus Rhodes grass has a comparatively stronger ability to compete with Navua sedge (Szymura et al. 2018), and maybe used as a candidate grass species in pasture field infested with Navua sedge.

ACKNOWLEDGMENTS

We sincerely thank the Queensland Department of Agriculture and Fisheries for partly funding this project and the University of Queensland for providing access to facilities. We also thank Stephen Setter and Melissa Setter for the help with seed collection of Navua sedge. This is dedicated to the memory of Ms Mogomotsi Moilwa who sadly passed away this year.

REFERENCES

Anwar, M., Akmal, M., Shah, A., Asim, M. and Gohar, R. (2012). Growth and yield comparison of perennial grasses as rainfed fodder production. *Pakistan Journal of Botany* 44, 547-552.

Dhileepan, K., Musili, P.M., Ntandu, J.E., Chukwuma, E., Kurose, D., Seier, M.K., Ellison, C.A. and Shivas, R.G. (2022). Fungal pathogens of Navua sedge (*Cyperus aromaticus*) in equatorial Africa as prospective weed biological control agents. *Biocontrol Science and Technology* 32, 114-120.

Falster, D.S. and Westoby, M. (2003). Plant height and evolutionary games. *Trends in Ecology & Evolution* 18, 337-343.

Prince, C.M., MacDonald, G.E., Ferrell, J.A., Sellers, B.A. and Wang, J. (2018). Impact of soil pH on Cogongrass (*Imperata cylindrica*) and Bahiagrass (*Paspalum notatum*) competition. *Weed Technology* 32, 336-341.

Radosevich, S.R. (1987). Methods to study interactions among crops and weeds. *Weed Technology* 1, 190-198.

Seavers, G. and Wright, K. (1999). Crop canopy development and structure influence weed suppression. *Weed Research* 39, 319-328.

Shi, B., Osunkoya, O.O., Chadha, A., Florentine, S.K. and Dhileepan, K. (2021). Biology, Ecology and Management of the Invasive Navua Sedge (*Cyperus aromaticus*)—A Global Review. *Plants* 10, 1851. doi:https://doi.org/10.3390/plants10091851

Szymura, M., Szymura, T., Wolski, K. and Świerszcz, S. (2018). Can native grass species outcompete invasive goldenrods? Results of a replacement series experiment. *Weed Research* 58, 304-317.

Vitelli, J.S., Madigan, B.A. and van Haaren, P.E. (2010). Control techniques and management strategies for the problematic Navua sedge (Cyperus aromaticus). *Invasive Plant Science and Management* 3, 315-326.

Vogler, W.D., Carlos, E.H., Setter, S.D., Roden, L. and Setter, M.J. (2015). Halosulfuron-methyl: A selective herbicide option for the control of the invasive *Cyperus aromaticus* (Ridley) Mattf. and Kukenth (Navua sedge). *Plant Protection Quarterly* 30, 61-66.