Illinois bundleflower: a perennial multiple purpose third crop for Iowa

Final Report for GNC05-055

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Grant Recipient: Iowa State University
Region: North Central
State: Iowa
Graduate Student:

Valentin Picasso

Faculty Advisor:

Dr. E. Charles Brummer
University of California - Davis

Project Information

Summary:

Illinois bundleflower (Desmanthus illinoensis), a perennial native legume, has potential for forage and grain production and therefore to diversify and perennialize agroecosystems in the North Central US. In chemical-free plots Illinois bundleflower produced 958 kg/ha of forage with 17 % protein, averaged over two years, and 140 kg/ha of seed in 2004 and 550 kg/ha in 2005 with 41 % of protein. Mixtures with grasses produced more total forage, and sometimes reduced weeds, but did not increase seed production. In no-till demonstration plots Illinois bundleflower produced less than 750 kg/ha of forage. Weeds limited Illinois bundleflower productivity in demonstration plots.

Introduction:

Current agricultural systems in the North Central US are based primarily on two annual crops, corn and soybean. These systems have various limitations, including erosion (NRC 1989, Pimmentel et al. 1995), water contamination with nutrients and pesticides resulting in hypoxia in the Gulf of Mexico (Golsby et al. 1999, Dinnes et al. 2002, Rabalais et al. 2002) and declining farmer income (USDA 2004, Duffy 2004). The sustainability of these cropping systems could be improved by increasing crop diversity, especially through incorporation of perennial species. Perennial agroecosystems such as pastures have low erosion rates and limited nutrient leaching, while also providing other ecosystem services (Altieri 1999, Jackson 1980, Daily et al 1997, Pimm 1997). Several SARE projects have documented the benefits of perennials for sustainable cropping systems (e.g. Casgrande 1990, Raich 2002, Wyse 2002). In addition to forage crops, perennial grain crops have been proposed and are being developed (Moffat 1995, Weik et al 2002, Jones 2003, Cox et al 2002).

Iowa has a long history of perennial landscapes, beginning with the tall grass prairie, and later including various hay and pasture species and fruit trees (Pirog and Paskiet 2004). Virtually all the tall grass prairie has been eliminated (Samson and Knopf 1994) and over two-thirds of the state's area is in annual grains, primarily corn and soybeans (USDA 2004). Although forages are central to changing towards perennial landscapes, edible perennial grains may also play a key role in Iowa culture. Native perennial species can be grown in CRP lands for conservation as an additional economic benefit.

Illinois bundleflower (Desmanthus illinoensis) is a promising perennial for both forage and grain production. This herbaceous warm-season legume is indigenous to the North American prairies. Its natural distribution ranges north from Minnesota to Colorado, and south from Texas to Florida (Latting 1961). Several studies confirmed the potential of Illinois bundleflower as forage (Muncrief and Heizer 1985, Posler et al 1993, Beran et al 2000, Byun et al 2004) yielding as high as 8.6 Mg.ha-1 in Minnesota. Forage quality of Illinois bundleflower is comparable with alfalfa (Caperoon et al 2002). Illinois bundleflower can fix substantial amounts of nitrogen (Byun et al 2004) and Rhizobia inoculants are available to farmers (Beyaut et al in preparation). In Kansas, Illinois bundleflower has produced 1700 kg.ha-1 of seed with 38% crude protein content (Kulakov et al 1990). It is currently being bred for forage and grain production (Kulakov 1999, Cox et al 2002, Ehlke 2002, De Haan et al 2003). The scarce research on management practices for Illinois bundleflower has focused on seed germination (Msiska and Call 1989, Call 1985), establishment in pastures (Schweitzer et al 1993, Dovel et al 1990) and competition with weeds (Beran et al 2000, Masters et al 2001).

Mixtures of legumes and grasses usually result in higher forage production, better nutritive value, and improved seasonal distribution than do monocultures (Baylor 1974). Other benefits of mixtures include reduction of erosion and weed invasion, and higher stand longevity than monocultures (Droslom and Smith 1976). Alfalfa overyielded in mixtures with cool-season (Sleugh et al. 2000) or warm-season grasses (George et al. 1995) in Iowa. Illinois bundleflower has shown compatibility in binary mixtures with warm-season grasses in Arkansas (Springer et al 2001). Evaluating the compatibility of Illinois bundleflower with cool and warm season grasses for forage and seed in Iowa is the goal of the research part of the project. This project follows from previous SARE projects to Wyse 2002 and Ehlke 1999. Ehlke (2002) stated that "the potential for grain production of Illinois bundleflower appears to be high; additional studies on grain yield/seed production must be performed in multiple environments to ensure sufficient levels of seed in the market for producers at a reasonable price."

Project Objectives:

The primary objective of this project is to assess the feasibility of growing Illinois bundleflower (Desmanthus illinoensis) as a third crop in Iowa. The project contributes to the long-term sustainability of the North Central US agriculture by combining research, education and extension activities towards the diversification and "perennialization" of local landscapes. The target population includes Iowa farmers, students, and the broad scientific community.
The project has three short-term outcomes: 1) scientific evidence of the feasibility of introducing a native legume species into a diverse perennial cropping system in Iowa; 2) specific information on the management of Illinois bundleflower as forage and/or grain crop in monoculture and in mixtures with cool and warm season grasses; and 3) increased awareness from local farmers of benefits of perennial third crops.

Results will lead to the intermediate-term outcomes of increasing the number of Iowa farmers diversifying their system with perennial third crops and increased scientific research on diverse perennial cropping systems in the North Central US. This project integrates research and extension to local farmers, which assures that the producer community will evaluate results; farmers' feedback will be incorporated for future directions.

Cooperators

- Charles Brummer

  brummer@uga.edu

  Professor

  University of Georgia

  111 Riverbend Rd.
  Athens, GA 30602

  (706) 542-8847 (office)

- Norman McCoy

  njmccoy@iastate.edu

  Farmer

  Practical Farmers of Iowa

  11395 N E Hubbell Ave
  Maxwell, IA 50161

- Valentin Picasso Risso

  vpicasso@iastate.edu

  PhD student in Sustainable Agriculture

  Iowa State University

  1301 Agronomy Hall
  Ames, IA 50011

  (515) 294-6795 (office)

Research

Materials and methods:

The design of this SARE project is based on the facts that (1) small-plot research on Illinois bundleflower management is needed before committing farmers to a crop that may not be beneficial to their systems and (2) many farmers are unfamiliar with the crop. Therefore, this project had three components: (1) experiments at two ISU research stations to determine the value of the crop, (2) an on-farm demonstration plot to assess practicality of growing the crop, and 3) education and

outreach activities to familiarize farmers with the crop.

Small plot experiments: Illinois bundleflower forage and grain productivity was determined in two controlled experiments that were established in April, 2003 at two Iowa State University research farms in Story and Boone Counties. The forage experiment included Illinois bundleflower in monoculture, in binary mixtures with two cool season grasses (orchardgrass [Dactylis glomerata] and intermediate wheatgrass [Agropyron intermedium]) and two warm season grasses (switchgrass [Panicum virgatum] and eastern gamagrass [Tripsacum dactyloides]), and in 3-species mixtures with two grasses from the same group. For comparison, the same combination of plots were included with alfalfa (Medicago sativa) as the legume. The first year was used to establish the warm season grasses, so measurement of biomass commenced in 2004. The experiment was a randomized complete block design with 3 replications per location. Each plot was 3 m x 2 m, and separated by other plots by a 1.5 m border area of turfgrass. Aboveground biomass was harvested with a flail-type mechanical harvester equipped with an electronic weigh system three times per growing season on a schedule similar to that of hay or rotational grazing. The percentage of bundleflower in the forage was determined at each harvest by hand separations of a subsample (0.18 m2) of forage clipped from each plot prior to harvest. Forage nutritive value (digestibility, crude protein, and fibers) was analyzed on the component species in the hand separated samples in the forage quality laboratory at ISU, based on methods described in Riday et al 2002. A second experiment evaluated seed production of Illinois bundleflower monocultures and in binary mixtures with promissory perennial grains (intermediate wheatgrass and eastern gamagrass). Plots (3 m x 2 m) were let grow and hand-harvested for seed. Data was collected in 2005 and 2006.

Demonstration plots: Two demonstration fields, of approximately 1 ha each, were established in spring 2006 on the farm of Mr. Norman McCoy in Polk County, Iowa. The goal was to evaluate the establishment and productivity of Illinois bundleflower in pure stands and in mixture with grass on a larger scale than small plots. The site covered two landscape positions (bottomland and hillside), allowing us to evaluate the performance of Illinois bundleflower over a range of microenvironments. In fall 2005 (October/November) gliphosate was applied on unmowed Brome pasture. In May 2006 gliphosate was applied again and seeds were later no-till drilled at a rate of 10 lb Illinois bundleflower seed/ac. Mixture plots were sown with Switchgrass (4 lb/ac) or Intermediate wheatgrass (4 lb/ac). During summer 2006 all plots were mowed twice and grazed with goats. In 2007 no mowing, fertilizers, or herbicides were applied. Biomass data was measured in 2007.

Outreach activities: A final objective of this project was to disseminate the results of our plot trials and demonstration project to farmers. In September 2007, we hosted a field day in conjunction with Practical Farmers of Iowa to show the plots and demonstration field and discuss the value of growing Illinois bundleflower. Additionally, we presented our results at one prairie extension meeting, and the project was communicated with one article written for the popular press. For the academic audience, we presented the results at a national conference and publish a scientific paper in a peer reviewed journal.

Research results and discussion:

Outcome 1 accomplishments (scientific evidence of the feasibility of growing Illinois bundleflower in Iowa): In all experimental plots (monocultures and polycultures) Illinois bundleflower was established, produced forage and seed, and re-grew the following year. In chemical-free experimental plots (without fertilizers, herbicides, or pesticides) monocultures of Illinois bundleflower produced 958 kg/ha of forage with

17 % protein, under three forage cuts per year, averaged over two years. Seed production in plots harvested once per year was 140 kg/ha in 2004 and 550 kg/ha in 2005 with 41 % of protein. In on-farm demonstration plots forage biomass of Illinois bundleflower was low, and limited by weed invasion, primarily Horseweed, a common weed in no-till systems.

Outcome 2 accomplishments (management of Illinois bundleflower as forage and/or grain crop in monoculture and in mixtures with cool and warm season grasses):

The main challenge for Illinois bundleflower production in chemical-free systems is competition with weeds, because this warm season legume starts growing late in the season (May) and does not provide good ground cover. Polycultures (mixtures) with cool season grasses (orchardgrass and intermediate wheatgrass) reduced weed invasion but also I. bundleflower performance; mixtures with warm season grasses (switchgrass and eastern gamagrass) did not affect either weed invasion or I. bundleflower performance, because they were slow growing and took longer to establish. In on-farm demonstration plots mixtures of Illinois bundleflower with switchgrass or intermediate wheatgrass were not able to suppress weeds significantly during the first year.

Outcome 3 accomplishments (awareness from local farmers of benefits of perennial third crops): A Practical Farmers of Iowa Field day was held on Norman Mc Coy Farm on September 9th 2007, with attendance of about 30 people. The importance of perennials and diversification of farming systems was discussed, as well as the first year results of the Illinois bundleflower project. Participants showed high interest in perennial alternative crops. Also results were communicated in a poster presentation at the Iowa Prairie Conference 2007, in Sioux City, IA. Finally, for the academic audience, a paper in Crop Science was published (Crop Science 48:331-342).

Table 1. Forage production of Illinois bundleflower (IBF) in monoculture and mixtures with cool season grasses (IWG=intermediate wheatgrass, OGR=orchardgrass) compared to alfalfa (ALF) in monoculture and mixtures in experimental small plots (2 x 3 m) under three harvests management system (June, August, and October) averaged over 2 years in central Iowa. Standard Error of means are shown.

Harvest First Second Third Total
kg/ha
IBF 53 594 310 958
ALF 3567 3581 1429 8578
IBF-IWG 848 1103 248 2199
IBF-OGR 1179 1191 526 2896
ALF-IWG 3401 3261 1487 8149
ALF-OGR 3250 3769 1980 8999

SE 204 204 204 303

Table 2. Percent protein and percent ND fiber of Illinois bundleflower (IBF) in monoculture and mixtures with cool season grasses (IWG=intermediate wheatgrass, OGR=orchardgrass) compared to alfalfa (ALF) in monoculture and mixtures in experimental small plots (2 x 3 m) under three harvests management system (June, August, and October) averaged over 2 years in central Iowa.

A. Percent Crude Protein
Harvest First Second Third Total
IBF 26 16 16 17
ALF 20 18 18 19
IBF-IWG 12 13 16 13
IBF-OGR 11 11 13 12

ALF-IWG 18 17 18 17
ALF-OGR 15 15 15 15

SE 0 0 1

B. Percent ND Fiber
Harvest First Second Third Total
IBF . 33 34 .
ALF 41 44 47 41
IBF-IWG 58 51 47 58
IBF-OGR 54 52 52 54
ALF-IWG 46 45 47 46
ALF-OGR 47 48 52 47

SE 1 1 1

Table 3. Weed biomass in plots with Illinois bundleflower (IBF) in monoculture and mixtures with cool season grasses (IWG=intermediate wheatgrass, OGR=orchardgrass) compared to alfalfa (ALF) in monoculture and mixtures in experimental small plots (2 x 3 m) under three harvests management system (June, August, and October) averaged over 2 years in central Iowa.

Harvest First Second Third Total
kg/ha
IBF 143 181 93 416
ALF 41 16 22 78
IBF-IWG 130 125 56 311
IBF-OGR 63 65 22 149
ALF-IWG 13 41 26 79
ALF-OGR 5 0 13 18

SE 14 14 14 24

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Participation Summary

Educational & Outreach Activities

PARTICIPATION SUMMARY:

Education/outreach description:

Theses:

Picasso, V. 2008. Diversity, productivity, and stability in perennial polycultures used for grain, forage, and biomass production. PhD Dissertation. Iowa State University, Ames, IA, USA.

Scientific Articles:

Picasso, V., E.C. Brummer, M. Liebman, P.M. Dixon, and B.J. Wilsey. 2008. Crop Species Diversity Affects Productivity and Weed Suppression in Perennial Polycultures under Two Management Strategies. Crop Science 48:331-342.
Picasso, V., E.C. Brummer, M. Liebman, P.M. Dixon, and B.J. Wilsey. 200x. Diversity affects productivity over time through complementarity and stability in perennial polycultures. (manuscript to be submitted to Crop Science).
Picasso, V., E.C. Brummer, M. Liebman. 200x. Seed yield, forage production, and competitive ability of perennial crops in polycultures. (manuscript o be submitted to Crop Science).

Conferences Presentations:

Wilke, B.J., E. Flemmig, V. Picasso, and S.S. Snapp. Perennial Crop Mixtures for Organic Grain Production. 19th Annual Organic Farming Conference (MOSES), La Crosse, WI, USA. February 2008.
Picasso, V. 2007. Illinois bundleflower: a native prairie species with multiple potential agricultural uses. Iowa Prairie Conference, Sioux City, IA, USA. July 2007.
Picasso, V. and E.C. Brummer. 2006. Plant diversity increases biomass productivity in perennial polycultures. Abstract and Poster. ASA-CSSA-SSSA Annual Meetings, Indianapolis, IN, USA, November 2006.
Picasso, V. and E.C. Brummer. 2005. Plant functional diversity increases biomass production in the establishment of perennial polycultures. p 643 in O'Mara, F.P. et al. [eds] XX International Grassland Congress: Offered papers. Dublin, Ireland. Wageningen Academic Publishers, The Netherlands.

Field day:

PFI Field Day September 9th 2007. Norman Mc Coy Farm, Maxwell, IA, USA.

Project Outcomes

Project outcomes:

This research provided basic information about the feasibility of growing Illinois bundleflower in Iowa, as well as information on management practices and compatibility with grasses. Future research is needed in order for this species to be adopted in farmers systems yet. Weed management in Illinois bundleflower should be a central focus of future research efforts.

Recommendations:

Areas needing additional study

- Weed management in Illinois bundleflower systems, specially the chemical free ones.
- Agronomic management of Illinois bundleflower for optimizing forage and grain production (planting densities, row spacing, fertility requirements).
- Compatible grasses for growing in mixtures with Illinois bundleflower which maximize weed control without reducing bundleflower performance.