Pak. J. Bot., 55(3): 1145-1155, 2023. DOI: http://dx.doi.org/10.30848/PJB2023-3(14)

INFLUENCE OF ENVIRONMENTAL HETEROGENEITY ON DISTRIBUTIONAL PATTERN OF BLUE PANIC GRASS (*PANICUM ANTIDOTALE* RETZ.) IN THE PUNJAB, PAKISTAN

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Abstract

Panicum antidotale Retz. is an evergreen, vigorous and C_4 perennial grass growing up to 1 to 3m in length. It is commonly known as Bansi grass, Murrot, Giant panic, Ghirri, Ghamur and blue panic belonging to a fascinating family (Poaceae), originated from Indo-Pakistan region, and now naturalized in arid and semiarid region. Forty-eight populations were collected from six habitats of the Punjab, i.e., agricultural fields, river canal banks, roadsides, saline habitats, uncultivated lands, graveyards and forest plantations and waterlogged / industrial wastes pollution to explore their important attributes associated with widespread distribution of this native species across environmental heterogeneity. Among agricultural fields, *P. antidotale* was the most abundant at *Brassica* field at Makhdoom Rasheed (MR). Among saline habitats, importance value and relative cover was the maximum in highly saline Pasrur (PS). Among waterlogged areas and industrial waste pollutions, ecological attributes were the maximum in industrial waste disposal channel Gojra (GOJ). In saline habitat, RD showed negative trend with increasing salinity, while RF and RC showed positive response along salinity gradient. Importance value (IV) showed liner trend with increase in salinity. Among roadsides, soil Ca^{2+}, NO_3^-, OM, ECe and pH showed strong association with RF in SUM, SR and JHG sites. It was concluded that climate, soil and other abiotic factors have significant effect on species composition and distributional pattern of widespread *Panicum antidotale* Retz. in the Punjab, Pakistan.

Key words: Abiotic factors, C_4 grass, Distributional pattern, Ecological attributes, Species composition.

Abbreviations: Ecological parameters: RD-Relative density; RF-Relative frequency; RC-Relative cover; IV-Importance value. **Weather attributes:** Max.T-Maximum temperature; Min.T-Minimum temperature. **Soil attributes:** ECe-Soil ECe; pH-Soil pH; OM-Organic matter; SP-Saturation percentage; Ca-Soil Ca^{2+}; K-Soil K^+; Na-Soil Na^+; Cl-Soil Cl^-; NO-Soil NO_3^-; PO-Soil PO_4^{3-}, CL-Clayey loam, L-Loam, LS-Loamy sand, SCL-Sandy clayey loam, SL-Sandy loam.

Collection sites: Agricultural fields (CM-Chowk Metla; DK-Dijkot; GR-Garha Mor; JHN-Jahanian; MR-Makhdom Rasheed; P14-Pull14; PC-Pull Chatha; SB-Science Block), **River/ canal banks:** (BS-Bahadur Shah; BC-Burewala canal banks; CW-Chechawatni; KP-Kartarpur; RR-Ravi river; RUJ-Rajana; SA-Sarai-Alamgir; TSP-Tiba Sultan Pur), **Roadsides (**AH-Abdul Hakeem; DG-D-Ground; JHG-Jhang road; KG-Kanhetti Garden; KLR-Khabekki Lake along roadside; SR-Sahiwal road; SUM-Sumandri; TTS-Toba Tak Singh), **Saline habitats:** (NK-Ninekasi; JL- Jhallar Lake; KKL-Kalar Kahar Lake; KL-Khabekki Lake; KML-Kamalia; LKR-Lilah Khushab road; MW-Machewal;PS-Pasroor), **Uncultivated lands/Graveyard/forest plantation:** (BWG-Burewala graveyard; DP-Daphar plantation; GM-Gagu Mandi; GW-Gutwala; KW-Kabeerwala; KDC-Khan da Chak; KHW-Khanewal; NS-Noor Shah), **Waterlogged areas/Industrial waste pollution: (**AL-Adda Lundu; GA-Ghazi Abad; GOJ-Gojra; HR-Harappa road; HS-Head Sidnai; SC- Sarwar Chowk; VC-Vehari city; PN-Phoolnagar).

Introduction

Environmental heterogeneity is a key feature of the Pakistan that contains exceptionally cold mountainous region in north and hot coastline of Arabian Sea in south (Hussain *et al*., 2020). Climatic factors such as maximum and minimum temperatures, annual rainfall, humidity and wind speed varies greatly across the country (Bhatti *et al*., 2019). Pakistan falls into subtropical region with an average rainfall more than 250mm, but arid regions have extremely low rainfall with less than 120mm. Pakistan receives the maximum annual rainfall during monsoon season from the months June to September (Hussain *et al*., 2020).

Environmental heterogeneity performs a fundamental role in maintenance of species diversity and distribution of plant species across a variety of spatial scales (Beck *et al*., 2021).On a wide range of spatial scale, the distribution of plants may vary with climatic, topographic, hygrospheric (edaphic) conditions, and other biotic and abiotic factors (Deak *et al*., 2021). These environmental variations are positively related with species composition and richness and have been implicated as major factors maintaining the local diversity (Deak *et al*., 2021).

Studies on vegetation in response to varied climate change are focused on variety of habitats in recent eras. A slight increase in salinity, drought or altitude can alter the entire vegetation structure, species composition and distributional patterns (Liu *et al*., 2018). Grasses usually exhibit more potential to adapt in environmental extremes, hence, grasses are widely distributed due to more resistance and tolerance across variety of habitats (Farrag *et al*., 2021). The wide distributional pattern of various plant species generally depends on their tolerance and resistance to extreme environmental condition (Hillmann *et al*., 2020).

Panicum antidotale Retz. is a robust C_4 perennial grass growing up to 1 to 3m in length. It is locally known as Bansi grass or Murrot (Nasim *et al*., 2018). The giant panic or blue panic belonging to a fascinating family (Poaceae), originated from Indo-Pakistan region, and now naturalized in arid and semiarid region around the globe (Javed *et al*., 2021). It is a summer growing grass that benefits from summer rains, mainly found in open places (along roadsides, irrigated areas, agriculture fields, sandy dunes) and rarely spread in disturbed areas (flooded areas, saline and wasteland habitats). It exhibits more plasticity than most of the grass species in their structural and functional features, enabling them to withstand in diverse environmental conditions (Chen *et al*., 2021). It is used as a forage for livestock and wildlife, because it provides high nutrients and production, and protecting the soil from wind and water erosion (Sallam *et al*., 2019).

Ecological factor like relative cover, importance value, relative frequency and density are most important attributes that significantly changes along diverse climatic condition (Shuaib *et al*., 2018). This can alter entire composition and structure of plants community, dominance of particular species and, functional and structural characteristics of native species (Lozano *et al*., 2020). It was hypothesized that climate, soil and other abiotic factors should have significant effect on species composition and distributional pattern of widespread *Panicum antidotale* Retz. in the Punjab, Pakistan.

Material and Methods

Surveys were carried out to explore the distributional pattern of *P. antidotale* across a variety of habitat types from Punjab Province, Pakistan. For ecological data, 48 sites were selected for sampling of vegetation from 14 different districts and each study site was isolated by at least 30-50 km (Fig. 1). Three transect line (100 m long) were laid at each study site and five quadrates were selected along each transect line. By using the method of Greig-Smith (1983), data for relative density, frequency and importance value were recorded.

Soil analysis: Rhizospheric soil was taken from each habitat at the depth of 20-30 cm to analyze the soil physicochemical characteristics. Dried sample (at least 200g) of soil was taken for making the saturation paste. Soil extract was used to measure the soil pH, ECe using Electrical Conductivity and pH meters respectively. Potassium (K^+), sodium (Na^+) and calcium (Ca^{2+}) ionic contents were determined by using the Flame Photometer (Jenway, PFP-7, Japan), while Digital Chloride Meter (Jenway, PCLM 3, China) was used to measure the chloride (Cl^-).

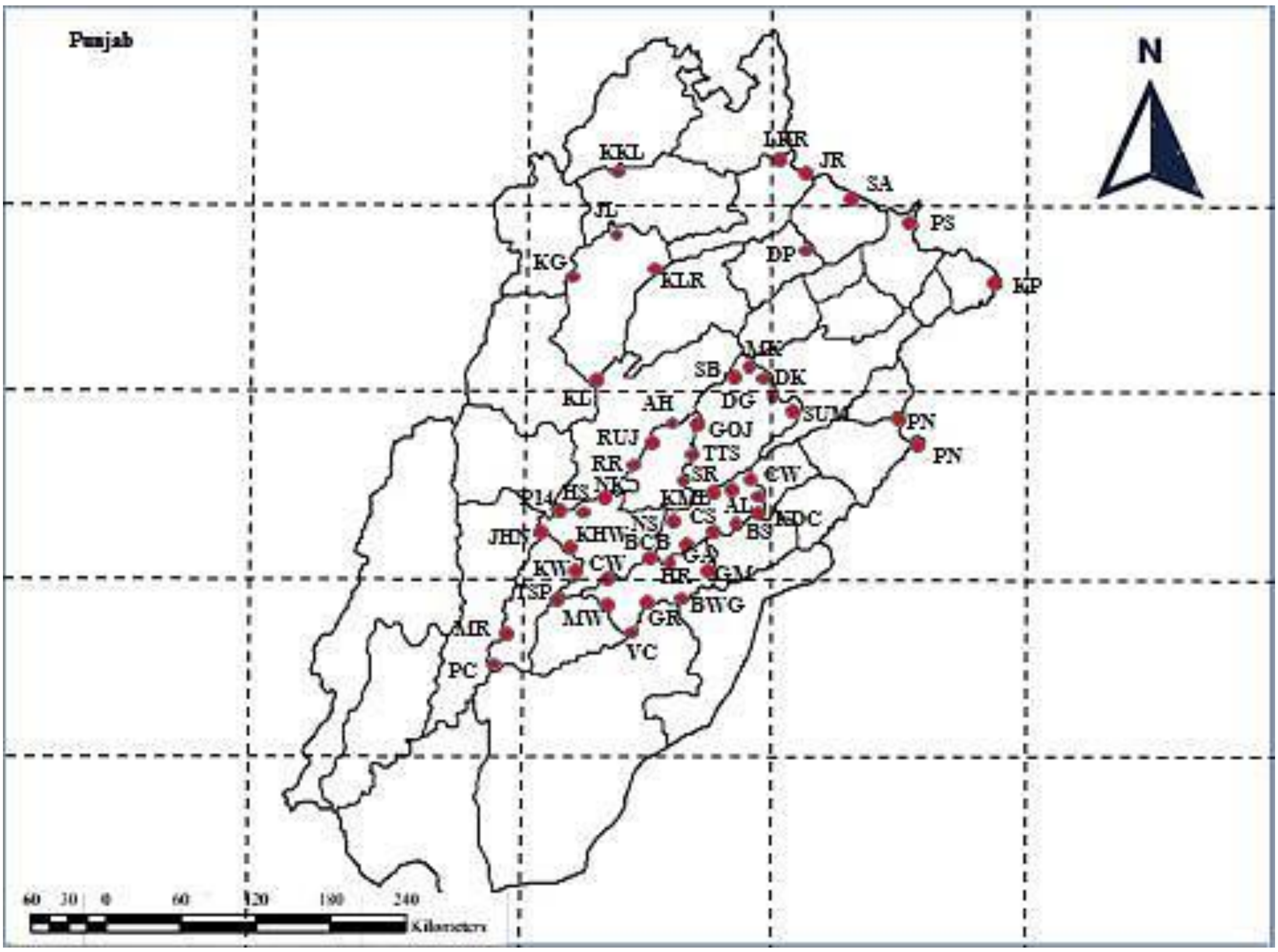

Fig. 1.Map of *Panicum antidotale* Retz. collection sites from the Punjab region.

Meteorological data: Meteorological data including annual temperature range (maximum and minimum) and annual rainfalls were obtained from the World Wildlife Fund (WWF) for the Nature Meteorological Station, Islamabad. This meteorological station maintains records for all sub-stations in collaboration with other organization in the country and is regulated by the Government of Pakistan.

Statistical analysis

The statistical software CanoDraw (version 4.14) was used to construct response curve and redundancy (RDA) analysis was used to determine the association of soil physicochemical characteristics with ecological attributes Canoco software (version 4.5).

Results

Weather: Among agricultural fields, SB received the maximum annual rainfall (375 mm). Mean annual temperature was the highest (51°C) and the lowest (4.5°C) at MR site. Among river canal banks, SB received the maximum annual rainfall (894 mm). Mean annual temperature was the highest (52°C) and the lowest (2°C) at BS site (Table 1). In roadside habitats, KLR received the maximum annual rainfall (600 mm year). Mean annual temperature was the highest (51°C) at SR and the lowest (1°C) at KLR site. In saline habitats, LKR received the maximum annual rainfall (375 mm year). Mean annual temperature was the highest (47°C) at MW site and the lowest (1°C) at JL, KKL and PS sites. Among uncultivated lands/graveyards/forest plantations, DP received the maximum annual rainfall (370 mm year). Mean annual temperature was the highest (52.7°C) and the lowest (2°C) at KDC site. Among waterlogged and industrial waste polluted areas, PN received the maximum annual rainfall (432 mm year). Mean annual temperature was the highest (51.7°C) at HR and the lowest (2°C) at SC and GA site (Table 1).

Soil physicochemical characteristics: Among agricultural fields, soil ECe ranged from 1.1(CM) to 1.6 dS m^{-1} (SB), pH from 8.2 (CM) to 8.8 (SB), Ca^{2+} from 43(P14) to 73 mg kg^{-1} (GR), K^+ from 47 (P14) to 71 mg kg^{-1} (GR), Na^+ from 45 (CM) to 76 (SB)mg kg^{-1}, Cl^- from 45 (CM) to 76 (SB) mg kg^{-1}, NO_3^- from 2.2 (P14) to 8.8 (GR) mg kg^{-1}, PO_4^{3-} from 3.2 (P14) to 15.9 (GR) mg kg^{-1}, saturation percentage from 27 (P14) to 34% (GR) and organic matter from 0.5 (P14) to 0.9 percent (GR). In river canal banks, soil ECe ranged from 1.1(BS) to 2.2 dS m^{-1} (TSP), pH from 8.0-(BS) to 8.7 (TSP), Ca^{2+} from 45(RUJ) to 95 mg kg^{-1} (BS), K^+ from 54 (RUJ) to 96 mg kg^{-1} (BS), Na^+ from 46 (BS) to 99 (TSP)mg kg^{-1}, Cl^- from 41 (BS) to 86 (TSP) mg kg^{-1}, NO_3^- from 1.7 (RUJ) to 4.5 (BS) mg kg^{-1}, PO_4^{3-} from 6.3 (RUJ) to 17.1 (BS) mg kg^{-1}, saturation percentage from 33 (RUJ) to 40% (BS) and organic matter from 0.5 (RUJ) to 0.8 percent (BS) (Table 2).

Among roadsides, soil ECe ranged from 1.0 (AH) to 1.4 dS m^{-1}, (TTS), pH from 8.0 (AH) to 8.6 (TTS), Ca^{2+} from 40 (KG) to 79 mg kg^{-1} (SR), K^+ from 54 (KG) to 77 mg kg^{-1} (SR), Na^+ from 30.2 (AH) to 74.6 (TTS) mg kg^{-1}, Cl^- from 30.4 (AH) to 67.4 (TTS) mg kg^{-1}, NO_3^- from 2.0 (KG) to 9.7 (SR) mg kg^{-1}, PO_4^{3-} from 3.5 (KG) to 15.9 (SR) mg kg^{-1}, saturation from 27.1 (KG) to 36.2 percent (SR) and organic matter from 0.7 (KG) to 1.0 percent (SR). Among saline habitats, soil ECe ranged from 7.5 (NK) to 32.4 dS m^{-1}, (PS), pH from 8.3 (NK) to 8.6 (PS), Ca^{2+} from 44.9 (MW) to 73.4 mg kg^{-1} (KML), K^+ from 44.5 (MW) to 71.8 mg kg^{-1} (KML), Na^+ from 2029.9 (NK) to 5661.3 (PS) mg kg^{-1}, Cl^- from 1783.9 (NK) to 3912.2 (PS) mg kg^{-1}, NO_3^- from 2.0 (MW) to 9.5 (KML) mg kg^{-1}, PO_4^{3-} from 3.3 (MW) to 10.1 (KML) mg kg^{-1}, saturation percentage from 33.1 (MW) to 40.1 (KML) and organic matter from 0.6 (MW) to 1.0 percent (KML) (Table 2).

Among uncultivated lands, graveyards and forest plantations, soil ECe ranged from 1.3 (BWG and DP) to 4.5 dS m^{-1} (NS), pH from 8.0 (BWG and DP) to 8.5 (NS), Ca^{2+} from 53.6(BWG and DP) to 152.6 mg kg^{-1} (NS), K^+ from 92.5 (BWG and DP) to 144.5 mg kg^{-1} (NS), Na^+ from 83.1 (BWG and DP) to 157.1 (NS) mg kg^{-1}, Cl^- from 62.2 (BWG, DP) to 143.3 (NS) mg kg^{-1}, NO_3^- from 2.5 (BWG, DP) to 5.6 (NS) mg kg^{-1}, PO_4^{3-} from 11.5 (BWG, DP) to 17.4 (NS) mg kg^{-1}, saturation percentage from 34 (BWG and DP) to 40 (NS) and organic matter from 0.5 (BWG, DP) to 1.0 percent (NS). Among waterlogged areas and industrial pollutions soil ECe ranged from 1.0 (AL) to 2.1 dS m^{-1} (PN), pH from 8.0 (AL) to 8.5 (PN), Ca^{2+} from 41.5 (AL) to 73.3 mg kg^{-1} (VC, SC and HS), K^+ from 45.5 (AL) to 76.5 mg kg^{-1} (VC, SC and HS), Na^+ from 43.1 (AL) to 78.8 (PN)mg Kg^{-1}, Cl^- from 37.8 (AL) to 73.9 (PN) mg kg^{-1}, NO_3^- from 3.7 (AL) to 8.6 (VC, SC and HS) mg kg^{-1}, PO_4^{3-} from 9.2 (AL) to 18.2 (VC, HS and SC) mg kg^{-1}, saturation from 36.4 (AL) to 45 percent (VC, SC and HS) and organic matter from 0.6 (AL) to 0.9 percent (VC, SC and HS) (Table 2).

Ecological parameter: Among agricultural fields, relative density was the maximum in MR and the minimum in SB site. Relative frequency and importance value was the maximum in MR and the minimum in CM. Relative cover was the highest in TW and the lowest in CM site. In river/canal banks, all ecological parameters were the maximum in CW and the minimum was recorded in RUJ. Among roadside populations, relative frequency and importance value was the maximum in AH and the minimum in SUM site. Relative density was the highest in AH and the lowest in SR and SUM sites. Relative cover was the maximum in JHG and the minimum in SR. In saline habitats, importance value and relative cover was the maximum in PS and the minimum in NK site. Relative density was the highest in LKR and the minimum in NK. Relative frequency was the maximum in PS and the minimum in KL. In uncultivated lands, graveyard and forest plantation, relative density and frequency were the maximum in KDC and the minimum in NS site. Relative cover was the maximum in GM and the minimum in NS. Importance value was the maximum in DP and the minimum in KDC site. Among waterlogged area and industrial waste pollution, all the ecological attributes relative density, frequency, cover and importance value was the maximum in GOJ and the minimum in AL site (Fig. 2 Table 3).

Table 1. Meteorological record of *Panicum antidotale* Retz. collection sites from different ecological regions of Punjab.

Habitats	Districts	Sites	Longitude (N)	Latitude (E)	Annual Rainfall(mm)	Annual temp.(°C)	
						Max.T	Min.T
Agricultural fields	Vehari	CM	30°04'20.74 "	71°56'38.84"	125	45	5
	Faisalabad	DK	31°13'55.92"	72°49'57.22"	365	48	5
	Vehari	GR	30°22'46.44"	72°23'20.59"	135	44	6
	Khanewal	JHN	30°08'55.42"	71°49'56.26"	145	47	8
	Multan	MR	30°06'02.26"	71°36'09.02"	175	51	4.5
	Khanewal	P-14	30°36'07.62"	72°49'36.36"	160	47	9
	Multan	PC	30°29'16.74"	71°38'19.26"	170	50	5
	Faisalabad	SB	31°35'39.84"	73°14'32.77"	375	48	5.5
Rivers/Canal banks	Sahiwal	BS	30°40'05.54 "	73°06'40.58"	349	52	2
	Vehari	BC	30°08'15.59"	72°43'10.98"	130	46	6
	Faisalabad	CW	30°33'14.23 "	72°43'13.97"	365.5	48.4	5.5
	Narowal	KP	32°35'16.59"	75°01'54.42"	894	43	5.4
	Toba Tek Singh	RR	30°35'35.33"	72°40'48.73"	267	46	5.2
	Toba Tek Singh	RUJ	30°61'13.87"	72°33'00.31"	268	47	5.5
	Gujrat	SA	32°55'30.45"	73°45'65.47"	692.4	49	5.5
	Multan	TSP	29°56'44.62"	71°53'48.67"	170.5	50.2	5
Roadsides	Khanewal	AH	32°45'12.45"	72°44'06.56"	162	46	7
	Faisalabad	DG	71°33'29.42"	73°53'09.42"	366	48.2	5.6
	Faisalabad	JHG	30°13'22.09"	71°44'56.22"	365.7	48.3	5
	Khushab	KG	32°44'13.44"	72°43'06.56"	401.3	36	2
	Khushab	KLR	32°04'46.15"	72°55'25.15"	600	43	1
	Sahiwal	SR	30°34'27.60"	72°52'36.28"	350	51	2
	Faisalabad	SUM	31°13'52.62"	72°57'07.06"	365.2	48.4	5.8
	Toba Tek Singh	TTS	30°58'15.37"	72°28'57.54 "	267.5	46.7	5.4
Saline habitats	Khanewal	NK	30°25'03.83"	71°52'47.13"	160	49	8
	Khushab	JL	32°39'53.33"	72°15'15.29"	401.3	42	1
	Chakwal	KKL	32°44'55.34"	71°43'00.29"	800	44	1
	Khushab	KL	32°36'08.66"	72°22'49.37"	500	43.5	2
	Toba Tek Singh	KML	30°44'19.87"	72°39'40.87"	267.3	46	5.1
	Jhelum	LKR	32°34'48.86"	72°59'19.32"	850	41.7	8.7
	Vehari	MW	30°29'15.69"	72°32'10.86"	132	47	4
	Sialkot	PS	30°39'32.47"	72°42'13.49"	250	42	1
Uncultivated lands/ graveyards/forest plantations	Vehari	BWG	30°29'5.49"	72°43'10.96"	135.5	45.5	5
	Mandi Bahauddin	DP	32°35'30.47"	73°20'16.79"	370	41.7	4.7
	Vehari	GM	30°23'17.46"	72°59'19.42"	125	45	6
	Faisalabad	GW	31°20'04.84"	73°22'01.41"	366	49	5.1
	Khanewal	KW	30°25'03.83"	71°41'47.23"	158	48	8
	Sahiwal	KDC	30°46'31.57"	72°41'53.99"	349.5	52.7	2
	Khanewal	KHW	30°27'11.20"	71°45'55.39"	155	49	9
	Sahiwal	NS	30°43'54.30"	72°45'29.59"	350	52	2.5
Water Logged area/ industrial waste pollutions	Vehari	AL	30°52'13.86"	72°53'34.44"	127	46.5	6
	Sahiwal	GA	30°24'54.42"	72°46'19.59"	349.2	51	2
	Toba Tek Singh	GOJ	31°29'01.23"	72°30'52.24"	267.7	45.5	5.7
	Sahiwal	HR	30°46'39.55"	72°43'34.54"	349.8	51.7	2.6
	Khanewal	HS	30°38'53.89"	72°29'04.48"	145	47	10
	Sahiwal	SC	30°68'44.73"	71°62'48.47"	350.4	51.4	2
	Vehari	VC	30°04'38.86"	72°30'38.45"	128.5	47.5	6.5
	Kasur	PN	31°13'20.82"	73°46'13.44"	432	49.7	13

Table legends: Agricultural fields (CM-Chowk Metla, DK-Dijkot, GR-Garha Mor,JHN-Jahanian, MR-Makhdoom Rasheed, P14-Pull-14, PC-Pull Chatha and SB-Science Block). **Rivers/canal banks** (BS-Bahadur Shah, BC-Burewala canal banks,CW-Chechawatni, KP-Kartarpur, RR-Ravi river, RUJ-Rajana, SA-Sarai-Alamgir and TSP-Tiba Sultan Pur). **Roadsides (**AH-Abdul Hakeem, DG-D-Ground, JHG-Jhang Road, KG-Kanhetti Garden, KLR-Khabekki Lake along roadside, SR- Sahiwal Road, SUM-Sumandri and TTS- Toba Tek Singh). **Saline habitats:** (NK-Ninekassi, JL-Jhallar Lake, KKL-Kalar Kahar Lake, KL-Khabekki Lake, KML-Kamalia, LKR-Lilah Khushab road, MW-Machewal and PS-Pasrur). **Uncultivated lands/graveyards/forest plantations:** (BWG-Burewala graveyard, DP- Daphar Plantation, GM-Gagu Mandi, GW-Gutwala, KW-Kabeerwala, KDC-Khan Da Chak, KHW-Khanewal, and NS-Noor Shah). **Water Logged area/industrial waste pollutions (**AL-Adda Lundu, GA-Ghazi Abad, GOJ-Gojra, HR-Harappa Road, HS-Head Sidhnai, SC-Sarwar Chowk, VC-Vehari city, and PN-Phool Nagar)

Table 2. Soil physicochemical characteristics of the *Panicum antidotale* Retz. collection sites from different ecological regions of Punjab.

Habitats	Sites	ECe	pH	OM	SP	Ca	K	Na	Cl	NO	PO	ST
Agricultural fields	CM	1.1c	8.2d	0.7b	30.2c	51.2cd	51.9cd	45.4de	38.8cd	3.8c	7.4de	L
	DK	1.2bc	8.2d	0.7b	32.1b	52.8cd	52.1cd	49.5d	43.4c	7.4b	11.2c	LS
	GR	1.3b	8.3c	0.9a	34.0a	73.4a	71.8a	59.4c	47.4c	8.8a	15.9a	L
	JHN	1.3b	8.7ab	0.8ab	29.1cd	55.8c	51.9cd	59.4c	47.4c	8.2ab	15.1ab	CL
	MR	1.3b	8.5b	0.8ab	28.2d	56.1c	55.1c	59.4c	47.4c	6.8bc	10.1d	L
	P-14	1.3b	8.3c	0.5c	27.0de	43.2de	47.5d	59.4c	47.4c	2.2e	3.2e	SL
	PC	1.5ab	8.7ab	0.6bc	29.1cd	47.9d	66.5b	68.5b	57.9b	3.3d	13.2b	LS
	SB	1.6a	8.8a	0.8ab	32.1b	65.6b	54.3c	76.8a	67.8a	7.4b	7.4de	SL
Rivers/Canal banks	BS	1.1d	8.0e	0.8a	40.0a	95.6a	96.5a	46.1d	41.4d	4.5a	17.1a	CL
	BC	1.4c	8.3b	0.6b	39.0ab	76.1c	84.7b	59.4c	54.7cd	3.9b	16.6ab	L
	CW	1.4c	8.1d	0.7ab	35.0d	63.8d	73.7c	59.4c	54.7cd	3.5bc	16.6ab	LS
	KP	1.5bc	8.1d	0.7ab	36.0cd	85.6b	64.2d	69.4bc	65.8c	3.1c	12.8b	SCL
	RR	1.5bc	8.3b	0.6b	37.0c	65.8d	85.7b	69.4bc	65.8c	2.6d	10.9c	CL
	RUJ	1.5bc	8.3b	0.5bc	33.0e	45.6e	54.7e	69.4bc	65.8c	1.7e	6.3de	LS
	SA	1.6b	8.2c	0.7ab	38.0b	85.6b	73.7c	79.8b	76.8b	2.2de	10.1c	SCL
	TSP	2.2a	8.7a	0.6b	35.0d	76.1c	65.2d	99.8a	86.6a	4.3ab	7.2d	L
Roadsides	AH	1.0e	8.0e	0.8c	29.0d	61.8c	75.7ab	30.2e	30.4cd	4.2bc	4.0d	CL
	DG	1.1d	8.5b	0.8c	29.0d	70.6b	66.7c	40.5d	37.5d	4.6b	6.9c	SL
	JHG	1.1d	8.4c	0.9b	32.2c	62.6c	60.1cd	41.6d	37.8d	3.6c	14.7ab	SL
	KG	1.2c	8.3d	0.7d	27.1de	40.0e	54.2d	52.9c	47.6c	2.0e	3.5e	SCL
	KLR	1.3b	8.3d	0.9b	34.0b	53.8d	66.7c	64.5b	57.5b	2.8d	9.6b	L
	SR	1.3b	8.3d	1.0a	36.2a	79.9a	77.9a	65.6b	56.4b	9.7a	15.9a	L
	SUM	1.3b	8.3d	0.8c	35.2ab	61.8c	75.7ab	64.4b	57.8b	4.7b	4.1d	L
	TTS	1.4a	8.6a	0.9b	34.1b	70.6b	71.1b	74.6a	67.4a	2.8d	7.0c	CL
Saline habitats	NK	7.5g	8.3d	0.8c	37.0d	51.2cd	49.5cd	2029.9e	1783.9f	9.0ab	6.6b	CL
	JL	8.5f	8.5b	0.8c	39.0b	52.8cd	53.1c	2460.8de	2068.5ef	4.6b	3.9d	SL
	KKL	9.4e	8.5b	0.9b	35.0f	56.2c	54.7c	2790.8d	2390.3e	3.0c	3.2f	L
	KL	15.2d	8.4c	0.9b	38.0c	55.8c	63.9b	3641.5c	3090.3d	3.0c	6.7b	SL
	KML	15.4d	8.4c	1.0a	40.1a	73.4a	71.8a	3641.5c	3090.3d	9.5a	10.1a	CL
	LKR	24.3c	8.4c	0.9b	36.0e	52.8cd	54.8c	4658.7bc	3417.8c	2.5d	6.4c	SCL
	MW	26.b	8.5b	0.6d	33.0g	44.9d	44.5d	4946.4b	3668.8b	2.0e	3.3de	LS
	PS	32.4a	8.6a	0.9b	35.0f	65.6b	68.3ab	5661.3a	3912.2a	2.5d	6.4c	L
Uncultivated lands/ graveyards/forest plantations	BWG	1.3e	8.0b	0.5cd	34.0bc	73.6e	92.5d	83.0e	62.2e	2.5d	11.5cd	SL
	DP	1.3e	8.0b	0.5cd	34.0bc	72.6e	92.5d	82.0e	62.2e	2.4d	11.6cd	L
	GM	1.4d	8.2ab	0.6c	35.2c	92.2d	102.5c	104.1d	82.0d	3.5c	14.2bc	SL
	GW	2.1c	8.4b	0.7bc	37.1b	112.6c	124.1b	126.8c	103.5c	4.6b	15.3b	SL
	KW	2.1c	8.4b	0.7bc	37.1b	112.6c	124.1b	128.5c	102.5c	4.5b	15.3b	SCL
	KDC	3.1ab	8.3ab	0.8b	39.0ab	132.2b	134.ab	143.4b	123.1b	5.1ab	16.5ab	L
	KHW	3.1ab	8.3ab	0.8b	39.0ab	132.2b	134.5ab	142.1b	122.2b	5.1ab	16.6ab	CL
	NS	3.5a	8.5a	1.0a	40.0a	152.6a	144.5a	157.1a	143.3a	5.6a	17.4a	SCL
Water Logged area/ industrial waste pollutions	AL	1.0c	8.0c	0.6c	36.4c	41.5d	45.5cd	43.6c	37.8c	3.7cd	9.2c	L
	GA	1.2bc	8.3b	0.8b	42.3ab	63.2b	63.8b	52.1bc	43.3b	6.4b	14.2b	SCL
	GOJ	1.2bc	8.3b	0.8b	42.1ab	62.9b	62.4b	54.1bc	43.3b	6.6b	13.9.b	L
	HR	1.2bc	8.3b	0.8b	42.2ab	63.5b	63.4b	53.1bc	43.3b	6.8b	14.1b	SL
	HS	1.4b	8.1bc	0.9a	45.0a	72.3a	75.5a	63.7b	53.2ab	8.3a	17.9a	SL
	SC	1.4b	8.1bc	0.9a	45.0a	73.5a	77.4a	63.7b	53.2ab	8.2a	18.2a	CL
	VC	1.4b	8.1bc	0.9a	45.0a	72.3a	76.5a	63.7b	53.2ab	8.8a	18.2a	CL
	PN	2.1a	8.5a	0.8b	40.2b	52.5c	51.8c	78.8a	63.9a	4.4c	12.1c	L

Soil attributes: ECe- Soil ECe (dS m^{-1}); pH-soil pH; OM-organic matter (%); SP-saturation percentage (%); Ca- Soil Ca^{2+} (mg kg^{-1}); K- Soil K^{+} (mg kg^{-1}); Na- Soil Na^{+} (mg kg^{-1}); Cl-Soil Cl^{-} (mg kg^{-1}); NO- Soil NO_3^{-} (mg kg^{-1}); PO- Soil PO_4^{3-} (mg kg^{-1}),

Soil texture: L-loam; CL-clayey loam; SL-sandy loam; SCL-sandy clayey loam.

Sites: Agricultural fields (CM-Chowk Metla, DK-Dijkot, GR-Garha Mor, JHN-Jahanian, MR-Makhdoom Rasheed, P14-Pull-14, PC-Pull Chatha and SB-Science Block). **Rivers/canal banks** (BS-Bahadur Shah, BC-Burewala canal banks, CW-Chechawatni, KP-Kartarpur, RR-Ravi river, RUJ-Rajana, SA-Sarai-Alamgir and TSP-Tiba Sultan Pur). **Roadsides (**AH-Abdul Hakeem, DG-D-Ground, JHG-Jhang Road, KG-Kanhetti Garden, KLR-Khabekki Lake along roadside, SR- Sahiwal Road, SUM-Sumandri and TTS-Toba Tek Singh). **Saline habitats:** (NK-Ninekassi, JL-Jhallar Lake, KKL-Kalar Kahar Lake, KL-Khabekki Lake, KML-Kamalia, LKR-Lilah Khushab road, MW-Machewal and PS-Pasrur). **Uncultivated lands/graveyards/forest plantations:** (BWG-Burewala graveyard, DP- Daphar Plantation, GM-Gagu Mandi, GW-Gutwala, KW-Kabeerwala, KDC-Khan Da Chak, KHW-Khanewal, and NS-Noor Shah). **Water Logged area/industrial waste pollutions (**AL-Adda Lundu, GA-Ghazi Abad, GOJ-Gojra, HR-Harappa Road, HS-Head Sidhnai, SC-Sarwar Chowk, VC-Vehari city, and PN-Phool Nagar)

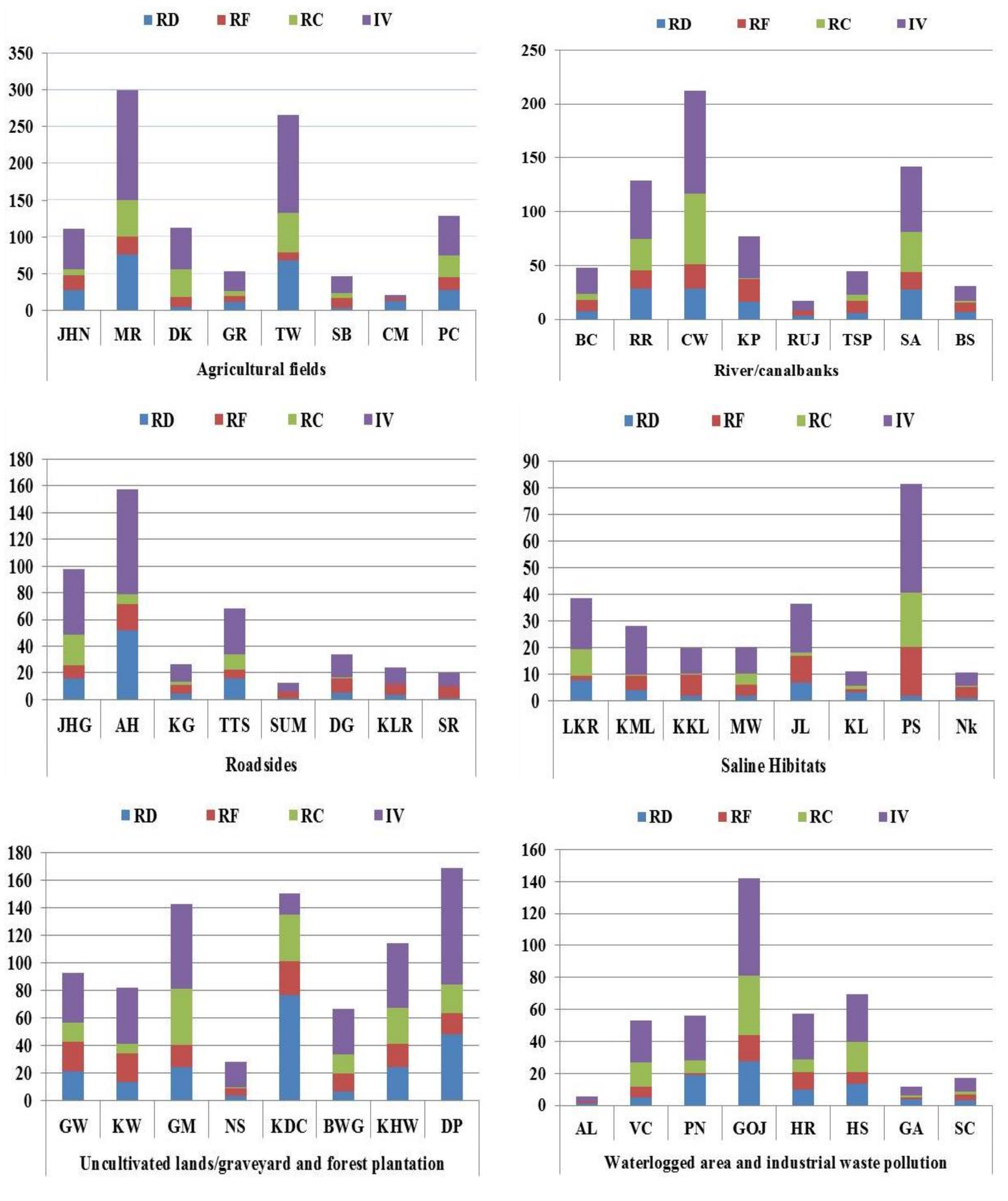

Fig. 2. Ecological parameters of *Panicum antidotale* Retz. collected from different habitats in the Punjab region.

Redundancy analysis: Soil Ca, NO and OM showed close association with RC at JHN and GR sites among agricultural fields. In river/canal banks, soil Na, Cl, NO, ECe and pH showed strong association with RD at KP, TSP and RR sites, while soil K, SP, PO and NO showed association with RC and IV at SA site. Among roadsides, soil Ca, NO, OM, ECe and pH showed close association with RF at SUM, SR and JHG sites (Fig. 3). In saline habitats, soil Na, Cl, K, ECe and pH were closely associated with RF at KKR and PS sites, while soil PO and SP were strongly associated with RD at LKR and JL sites. Among uncultivated lands, soil Ca, NO, OM, Na, Cl, PO, SP, ECe and pH showed strong association with RC at GW, DP and BWG sites. In waterlogged area and industrial waste pollution, the soil Na, Cl, ECe, pH showed close association with RF and IVat HS and PN sites, while soil OM, SP, PO, NO, K and K have an association with RC at HR and SC sites (Fig. 3).

Response curves: Response curves were constructed at each habitat types along salinity gradient. Among agricultural fields, all ecological attributes RD, RF, RC and IV showed a negative trend along salinity gradient. In river/canal bank, RD, RF, RC and IV showed negative slope along increasing salinity gradient. In roadsides, all ecological attributes showed negative trend with increase in salinity (Fig. 4). Among waterlogged and industrial waste polluted areas, RD, RF, RC and IV showed negative slope along salinity gradient. In saline habitats, RD showed negative trend with increasing salinity, while RF and RC showed positive response along salinity gradient. Importance value (IV) showed liner trend with increase in salinity. Among uncultivated lands, graveyards and forest plantations, RD and IV showed positive slope, while RC showed linear slope. RD showed negative slope along salinity gradient (Fig. 4).

Discussion

Environmental heterogeneity plays a fundamental role in maintenance of species diversity and distribution of plant species, so each study site had unique associated species. *Brassica* field at Makhdoom Rasheed (Multan) was dominated by 3 associated species along with *P. antidotale.* These were *Cynodon dactylon, Desmostachya bipinnata* and *Vachellia nilotica.* The most dominated, *Cynodon dactylon,* is a cosmopolitan species. This species is an excellent fodder grass and valuable pasture in tropical and subtropical region (Wang *et al*., 2020). In Dijkot (District Faisalabad), *Panicum antidotale* was the most dominated species along with *C. dactylon.* The agricultural weeds associated with *P. antidotale* were *Chenopodium murale, Rumex dentatus* and *Amaranthus viridis.* Weeds in agriculture land are reported as the most dangerous pest, with an expected annual global loss estimated at 40 million US dollars (USD) per year (Hulme *et al*., 2022). Weeds decrease crop quality and productivity in competition with crops for water, minerals and sunlight (Kumar *et al*., 2021), producing allelopathic compounds, disruptive harvesting and tilling (Kumar *et al*., 2021) and hosting diseases and pests (Ghanizadeh *et al*., 2021).

River Ravi population was collected near bank of canal Ravi in district Toba Tak Singh having loamy clay soil that was dominated by *P. antidotale.* The other dominated associated species were *Dalbergia sissoo, Malvastrum coromandelianum* and *Cirsium arvense*. One of the best significant functions of canal bank vegetation (riparian vegetation) is its capability to overcome erosion and inhibit sediment pollution in canal, stream or river (Vashistha *et al*., 2021).

Table 3. Ecological characteristics of *Panicum antidotale* Retz. collection sites from different ecological regions of Punjab.

Collection site	Associated species
Agricultural fields	
CM	*Desmostachya bipinnata, Sporobolus arabicus* and *Vachellia nilotica*
DK	*Chenopodium murale, Rumex dentatus* and *Amaranthus viridis*
GR	*Sporobolus arabicus, Prosopis glandulosa* and *Vachellia nilotica*
JHN	*Cenchrus pennisetiformis, Suaeda vera* and *Sonchus oleraceus*
MR	*Cynodon dactylon, Desmostachya bipinnata* and *Vachellia nilotica*
P-14	*Cenchrus pennisetiformis, Sisymbrium irio* and *Cenchrus setigerus*
PC	*Cynodon dactylon, Dalbergia sissoo* and *Vachellia nilotica*
SB	*Ochthochloa compressa, Dichanthium annulatum* and *Cynodon dactylon*
River/Canal banks	
BS	*Dalbergia sissoo, Cenchrus pennisetiformis* and *Cynodon dactylon*
BC	*Bombax ceiba, Chenopodium murale* and *Cynodon dactylon*
CW	*Cenchrus pennisetiformis, Albizia procera* and *Sonchus oleraceus*
KP	*Cynodon dactylon, Syzygium cummunii* and *Dichanthium annulatum*
RR	*Dalbergia sissoo, Malvastrum coromandelianum* and *Cirsium arvense*
RUJ	*Cynodon dactylon, Euphorbia helioscopia* and *Oxalis corniculata*
SA	*Cynodon dactylon, Vicia sativa* and *Medicago lupulina*
TSP	*Cenchrus pennisetiformis, Cynodon dactylon* and *Dichanthium annulatum*
Roadsides	
AH	*Cenchrus ciliaris, Crotalaria burhia* and *Desmostachya bipinnata*
DG	*Salsola baryosma, Dichanthium annulatum* and *Cynodon dactylon*
JHG	*Aristida adscensionis, Dipterigium glaucom* and *Lasiurus scindicus*
KG	*Cymbopogon jwarancusa, Senegalia modesta* and *Justicia adhatoda*
KLR	*Chrysopogon serrulatus, Senegalia modesta* and *Cymbopogon jwarancusa*
SR	*Cynodon dactylon, Eucalyptus camaldulensis* and *Tripidium bengalense*
SUM	*Eucalyptus camaldulensis, Cynodon dactylon* and *Saccharum munja*
TTS	*Cannabis sativa, Morus alba* and *Achyranthes aspera*

Table legends: Agricultural fields (CM-Chowk Metla, DK-Dijkot, GR-Garha Mor, JHN-Jahanian, MR-Makhdoom Rasheed, P14-Pull-14, PC-Pull Chatha and SB-Science Block). **Rivers/canal banks** (BS-Bahadur Shah, BC-Burewala canal banks, CW-Chechawatni, KP-Kartarpur, RR-Ravi river, RUJ-Rajana, SA-Sarai-Alamgir and TSP-Tiba Sultan Pur). **Roadsides (**AH-Abdul Hakeem, DG-D-Ground, JHG-Jhang Road, KG-Kanhetti Garden, KLR-Khabekki Lake along roadside, SR- Sahiwal Road, SUM-Sumandri and TTS- Toba Tek Singh)

Jhang road (District Faisalabad) near Kohistan Adda facing heavy traffic load was dominated by *P. antidotale*. Other dominated associated species were *Aristida adscensionis, Dipterygium glaucum* and *Lasiurus scindicus*. Biodiversity of urban roadside plants facing heavy traffic load and acts as an eco-sustainable filter for air pollution (Klaus *et al*., 2021). Urbanization leads to the fragmentation of ecosystems according to species depending on their ecological attributes. Paradoxically, the urbanization process creates uninhabited areas, wasteland, settlements that can contribute to the conservation of biodiversity in urban areas (Vega *et al*., 2021). Sumandri site, a muddy wasteland along roadside, was dominated by *Eucalyptus camaldulensis, Cynodon dactylon* and *Saccharum munja* along with *P. antidotale*. The other colonizing species were *Acacia jacquemontii, Achyranthes aspera, Cannabis sativus, Chenopodium album, Convolvulus arvensis, Conyza ambigua, Cynodon dactylon, Dalbergia sissoo, Desmostachya bipinnata* and *Eucalyptus camaldulensis*. Urban roadside wastelands can provide habitat for rare plants and animals (Vega *et al*., 2021). Thus, Nizamani *et al*., (2021) and Klaus *et al*., (2021) suggests that advanced rehabilitation strategies in urban roadside wasteland areas may provide a conducive habitat for the conservation of endemic plant species in intensive agricultural areas. Highly competitive plant species benefit greatly in such an environment (Vega *et al*., 2021).

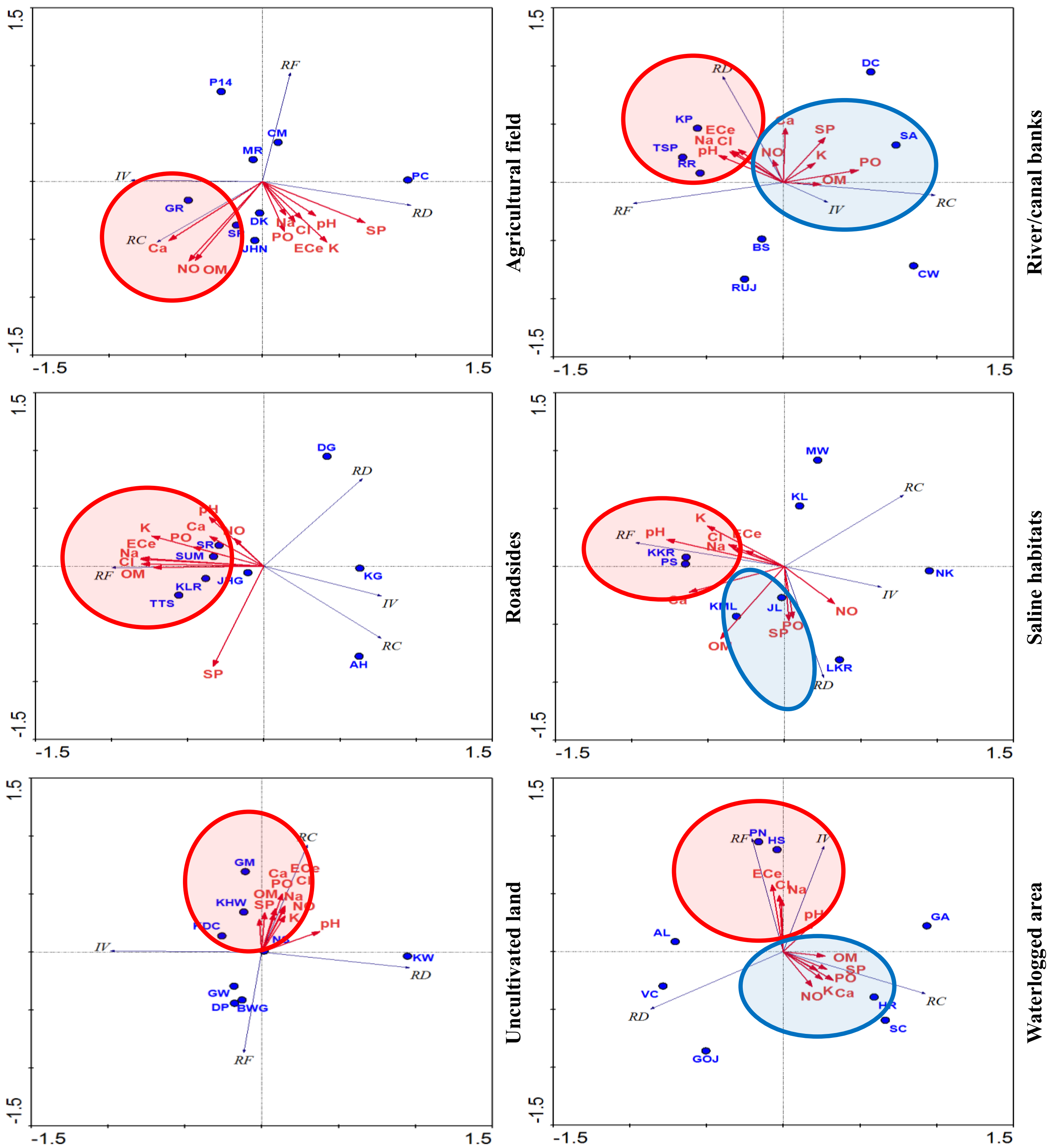

Fig. 3. Redundancy analysis (RDA) triplots of *Panicum antidotale* Retz. collection sites from the Punjab region.

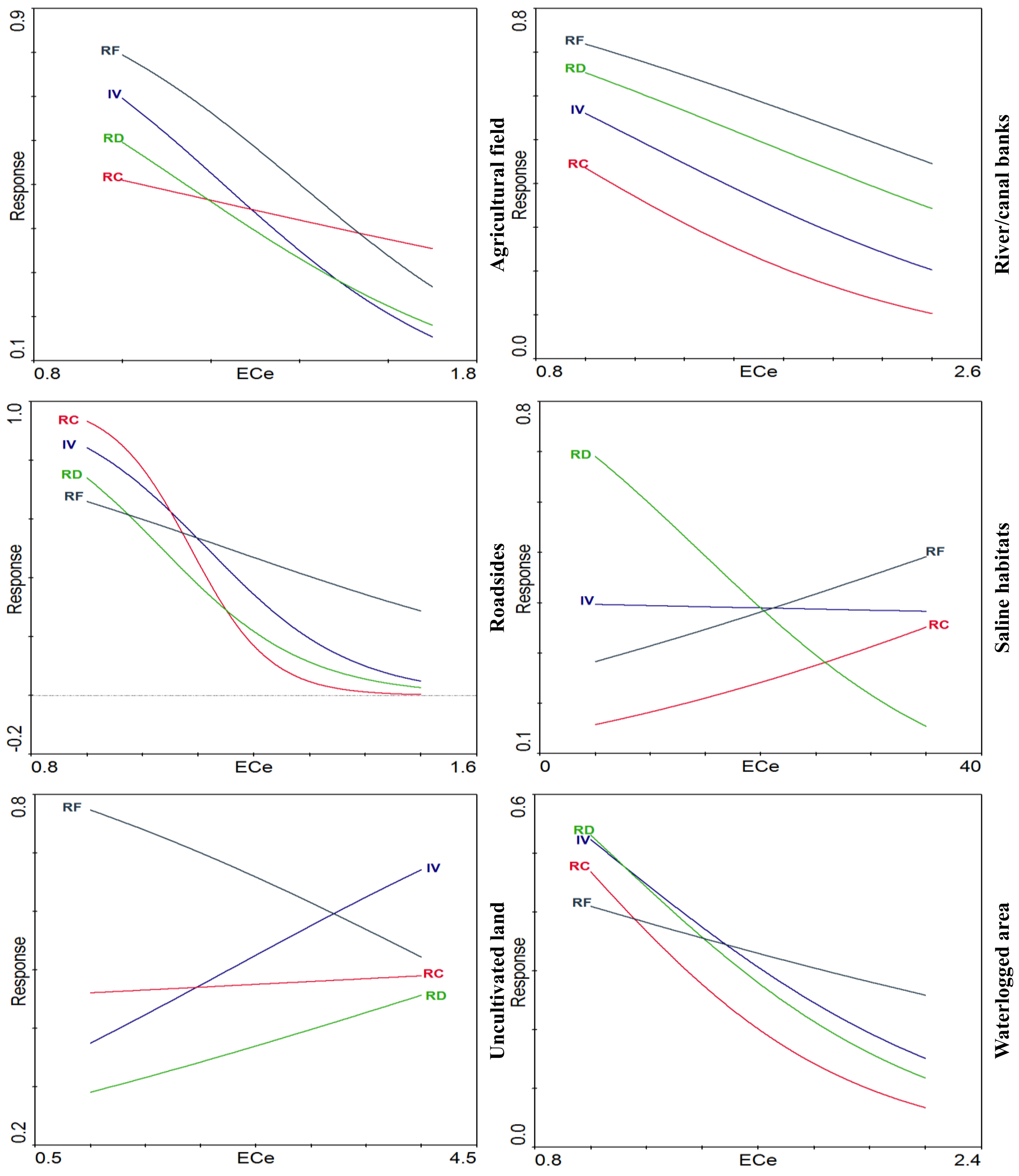

Fig. 4. Response curve developed along salinity gradients (0 to 40 dS m^{-1} left to right) of *Panicum antidotale* Retz. collection sites from the Punjab region.

Jhallar Lake, a picturesque saltwater lake in the southern Salt Range, was invaded by *P. antidotale* along with other associated species comprised of *Cymbopogon jwarancusa, Senegalia modesta* and *Maytenus royleanus.* The other colonizing species were *Heteropogon contortus, Justicia adhatoda, Lantana camara, Lantana indica, Maytenus royleanus, Otostegia limbata, Periploca aphylla, Pupalia lappacea* and *Ziziphus nummularia.* Salinity is a major obstacle to the sustainability of the ecosystem and poses many restrictions on native flora and fauna. In recent decades, problem of salinization has significantly increased as a result of poor irrigation system, improper agricultural practices, soil erosion, poor drainage system and human activities (Cui *et al*., 2021). Lilah (District Jhelum) is heavily salt-affected land comprised of most associated species *Dipterygium glaucum, Calligonum polygonoides* and *Lasiurus scindicus* along with *P. antidotale.* High concentration of salts in water and soils exerts negative effect on plant biochemical characters by disturbing ionic and osmotic stability in plants (Nguyen *et al*., 2020). This results in significant osmotic imbalances that disrupt multiple physiological processes, especially photosynthesis. Such an overload of ionic contents in salt affected land causes oxidative damage and denatures the lipid metabolism and protein synthesis and ultimately affects the fundamental stages of development in plants (Galliari *et al*., 2021). In Burewala (District Vehari), a uncultivated land near graveyard of Burewala were dominated by *Imperata cylindrica, Lepidium didymum* and *Eucalyptus torelliana.* Uncultivated lands are those ecosystems in which less than one third of the area has vegetation in its natural wild state that has been completely or partially cleared (Khan *et al*., 2016). Rates of vegetation abandonment are increasing in arid and semi-arid regions and uncultivated fields due to lower ecosystem performance and biodiversity (Zereen *et al*., 2018). Long-lasting, drought-tolerant grasses, shrubs and trees are an integral part of multiple arid ecosystems, providing many ecosystem services such as herbaceous plant assistance, soil stabilization, carbon storage and wildlife habitat (Khan *et al*., 2019). Gutwala plantation was dominated by *P. Antidotale* along with other associated species like *Eucalyptus camaldulensis, Malvastrum coromandelianum* and *Oxalis corniculata.* Gutwala is important Artificial Forest Plantation area due to conservation of numerous endangered species therein (Hameed *et al*., 2011).

In Phoolnagar (District Kasur) a brackish waterlogged area near link road Phoolnagar to Lahore was completely dominated by *P. antidotale* along with other associated species were *Dalbergia sissoo, Cynodon dactylon* and *Xanthium strumarium.* Waterlogging is one of the serious problems in high rain-fed areas suffered by plants. During such situation aerobic respiration is inhibited and limits energy metabolism, seed germination, growth and development (Kim *et al*., 2021; Xie *et al*., 2020). Vehari site the industrial waste disposal land, the most associated species was *Phragmites karka, Cyperus laevigatus* and *Cenchrus setigerus* along with *P. antidotale.* The effects of industrial chemical waste were studied and their ecological effect on plants and soil (organic matter, pH, calcium carbonate, inorganic phosphorus, exchangeable potassium and sodium) was shown to be significantly affected by waste disposal and subject to disturbed plant species, only halophytic and highly competitive plant species benefit greatly in such an environment (Hasan *et al*., 2021).

Conclusion

It was concluded that the distribution of *P. antidotale* was not influenced by any single abiotic factor. Water availability, salinity, temperature and annual rainfall collectively determined its distributional pattern. The soil contents and climate were the main contributors. Importance value was increased in agricultural fields whereas relative density and frequency was increased in uncultivated lands, graveyard and forest plantations. The populations of uncultivated lands, graveyard and forest plantations showed strong association of soil attributes like ECe, pH, Ca^{2+}, K^+, Na^+, Cl^-, organic matter, NO_3^- and saturation percentage, and with RC. Overall, the *P. antidotale* was more abundant in agricultural fields, river/canal banks, roadside and uncultivated lands.

References

Beck, J.J. and T.J. Givnish. 2021. Fine-scale environmental heterogeneity and spatial niche partitioning among spring-flowering forest herbs. *Amer. J. Bot.*, 108: 63-73.

Bhatti, M.T., W. Ahmad, M.A. Shah and M.S. Khattak. 2019. Climate change evidence and community level autonomous adaptation measures in a canal irrigated agriculture system of Pakistan. *Climate Dev*., 11: 203-211.

Chen, T., J.F. White and C. Li. 2021. Fungal endophyte *Epichloe bromicola* infection regulates anatomical changes to account for salt stress tolerance in wild barley (*Hordeum brevisubulatum*). *Plant Soil.*, 461: 533-546.

Cui, Q., T. He, A. Zhang, X. Quan, Y. Feng, X. Chen and Y. He. 2021. Effects of soil salinity characteristics on three habitats in inland salt marshes. *J. Plant Res.,* 134: 1037-1046.

Deak, B., B. Kovacs, Z. Radai, I. Apostolova, A. Kelemen, R. Kiss and O. Valko. 2021. Linking environmental heterogeneity and plant diversity: The ecological role of small natural features in homogeneous landscapes. *Sci. Total Environ.,* 763: 144199.

Farrag, K., S.G. Abdelhakim, A.R. Abd El-Tawab and H. Abdelrahman. 2021. Growth response of blue panic grass (*Panicum antidotale*) to saline water irrigation and compost applications. *Water Sci.*, 35: 31-38.

Galliari, J., L. Santucci, L. Misseri, E. Carol and M. del Pilar Alvarez. 2021. Processes controlling groundwater salinity in coastal wetlands of the southern edge of South America. *Sci. Total Environ.*, 754: 141951.

Ghanizadeh, H. and K.C. Harrington. 2021. Herbicide resistant weeds in New Zealand: state of knowledge. *New Zeal. J. Agric. Sci.*, 64: 471-482.

Greig-Smith, P. 1983. Quantitative Plant Ecology (Vol. 9). University of California Press, USA.

Hameed, M., R. Khan, M. Ashraf, T. Nawaz, M.S.A. Ahmad and S. Mubarik. 2011. Influence of plantation type on ground flora composition and diversity in Gatwala artificial forest plantation. *Pak. J. Bot.*, 43: 1867-1872.

Hasan, S.M., M. Akber, M. Bahar, M.Islam, M. Akbor, M. Siddique and A. Bakar. 2021. Chromium contamination from tanning industries and phytoremediation potential of native plants: a study of savar tannery industrial estate in Dhaka, Bangladesh. *Bull. Environ. Cont. Toxicol*., 106: 1024-1032.

Hillmann, E.R., V.H. Rivera-Monroy, J.A. Nyman and M.K. La Peyre. 2020. Estuarine submerged aquatic vegetation habitat provides organic carbon storage across a shifting landscape. *Sci. Total Environ.*, 717: 137217.

Hulme, P.E. and W. Liu. 2022. Species prevalence and plant traits discriminate between herbicide resistant and susceptible weeds. *Pest Manage. Sci.*, 78: 313-320.

Hussain, M., A.R. Butt, F. Uzma, R. Ahmed, S. Irshad, A. Rehman and B. Yousaf. 2020. A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan. *Environ. Monit. Assess.,* 192: 1-20.

Javed, M., M. Ashraf, M. Iqbal, M.A. Farooq, Z.U. Zafar and H.U.R. Athar. 2021. Chlorophyll fluorescence, ion uptake, and osmoregulation are potential indicators for detecting ecotypic variation in salt tolerance of *Panicum antidotale* Retz. *Arid Land Res. Manage.,* 86: 1-25.

Khan, A.M., R. Qureshi and Z. Saqib. 2019. Multivariate analyses of the vegetation of the western Himalayan forests of Muzaffarabad district, Azad Jammu and Kashmir, Pakistan. *Ecol. Ind.,* 104: 723-736.

Khan, M.A., J.A. Khan, Z. Ali, I. Ahmad and M.N. Ahmad. 2016. The challenge of climate change and policy response in Pakistan. *Environ. Earth Sci.*, 75: 1-16.

Kim, S.H., P. Tripathi, S. Yu, J.M. Park, J.D. Lee, Y.S. Chung and Y. Kim. 2021. Selection of tolerant and susceptible wild soybean (*Glycine soja* Siebold & Zucc.) accessions under waterlogging condition using vegetation indices. *Pol. J. Environ. Stud.*, 30: 3659-3675.

Klaus, V.H. and K. Kiehl. 2021. A conceptual framework for urban ecological restoration and rehabilitation. *Basic Appl. Ecol*., 52: 82-94.

Kumar, J.D., C.G. Babu and K. Priyadharsini. 2021. An experimental investigation to spotting the weeds in rice field using deepnet. *Materia Today*, 45: 8041-8053.

Liu, H., Z. Mi, L.I. Lin, Y. Wang, Z. Zhang, F. Zhang and J.S. He. 2018. Shifting plant species composition in response to climate change stabilizes grassland primary production. *Proc. Natl. Acad. Sci.,* 115: 4051-4056.

Lozano, Y.M. and M.C. Rillig. 2020. Effects of microplastic fibers and drought on plant communities. *Environ. Sci. Technol.*, 54: 6166-6173.

Nasim, F.U.H., A. Naureen, M. Saleem, N. Riaz, M.S. Choudhary and M. Ashraf. 2018. PAAN135, a novel rhizospheric fungus associated with Cholistan Desert grass *Panicum antidotale*, is a species of Saccharomycetales and a new source of cyclo-L-prolylglycine diketopiperazine. *Symbiosis,* 74: 121-130.

Nguyen, K.A., Y.A. Liou, H.P. Tran, P.P. Hoang and T.H. Nguyen. 2020. Soil salinity assessment by using near-infrared channel and vegetation soil salinity index derived from Landsat 8 OLI data: a case study in the Tra Vinh Province, Mekong Delta, Vietnam. Prog. *Earth Planet Sci.*, 7: 1-16.

Nizamani, M.M., U.A. Bhatti, X.L. Cheng, F.G. Nizamani, R.A. Rind, A.A. Khokhar and D.M. Yang. 2021. The connections between above-ground biomass and plant diversity of roadside trees, density and diversity on different types of roads in Karachi. *Pol. J. Environ. Stud.*, 30: 2691-2700.

Sallam, S.M.A., M.M.H. Khalil, M.F.A. Attia, H.M. El-Zaiat, M.G. Abdellattif, H.M. Abo-Zeid and M.M. Zeitoun. 2019. Utilization of blue panic (*Panicum antidotale*) as an alternative feed resource for feeding Barky sheep in arid regions. *Trop. Ani. Health Prod.,* 51: 2351-2360.

Shuaib, M., K. Ali, S. Ahmed, F. Hussain, M. Ilyas, N. Hassan and F. Hussain. 2018. Impact of rapid urbanization on the floral diversity and agriculture land of district Dir, Pakistan. *Acta Ecol. Sin.,* 38: 394-400.

Vashistha, G., N.A. Mungi, J.W. Lang, V. Ranjan, P.M. Dhakate, F.A. Khudsar and D. Kothamasi. 2021. Gharial nesting in a reservoir is limited by reduced river flow and by increased bank vegetation. *Sci. Reports*, 11: 1-12.

Vega, K.A., J. Schlapfer-Miller and C. Kueffer. 2021. Discovering the wild side of urban plants through public engagement. *Plants People Planet,* 3: 389-401.

Wang, M., J. Zhang, Z. Guo, Y. Guan, G. Qu, J. Liu and X. Yan. 2020. Morphological variation in *Cynodon dactylon* (L.) Pers., and its relationship with the environment along a longitudinal gradient. *Hereditas*, 157: 1-11.

Xie, L.N., Z.M. Ge, Y.L. Li, S.H. Li, L.S. Tan and X.Z. Li. 2020. Effects of waterlogging and increased salinity on microbial communities and extracellular enzyme activity in native and exotic marsh vegetation soils. *Soil Sci. Soc. Am. J.*, 84: 82-98.

Zereen, A., S.S. Ahmad and A. Jahan. 2018. Determination of correlation between plant distribution and ecological factors in Narowal district Punjab, Pakistan. *Bangladesh J. Bot.*, 47: 451-458.

(Received for publication 17 December 2021)